CBO PAPERS

THE TECHNOLOGY REINVESTMENT PROJECT: INTEGRATING MILITARY AND CIVILIAN INDUSTRIES

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PREFACE

The end of the Cold War provides the United States with significant benefits as well as some difficult challenges. One such challenge will be easing the transition of the U.S. industrial base to technologies and products that have both military and civilian uses. In light of the extraordinary difficulty of this task, the Congress appropriated $927 million for fiscal year 1993 through the Defense Department for research and development programs that promote dual-use technologies. Unlike other defense conversion programs established to help dislocated workers and communities, much less is known about how programs that assist the industrial base will be implemented.

At the request of Senator Jim Sasser, the Chairman of the Senate Budget Committee, this Congressional Budget Office (CBO) paper describes eight programs contained within the Defense Conversion, Reinvestment, and Transition Assistance Act of 1992 that were designed to help defense-oriented firms emphasize dual-use production. In keeping with CBO's mandate to provide objective and nonpartisan analyses, the paper makes no recommendations.

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SUMMARY

On March 11, 1993, President Clinton announced a five-year initiative costing more than $19 billion designed to ease the effects of the downturn in military spending on defense workers, communities, and the industrial base. Of that amount, nearly three-fourths is directed toward high-technology programs that encourage firms to produce civilian and dual-use goods (products that have both military and civilian markets). The remainder will help retrain defense workers and assist communities hard hit by military cutbacks.

Eight Department of Defense programs that were created within the Defense Conversion, Reinvestment, and Transition Assistance Act of 1992 form part of the Clinton initiative. Collectively, they are known as the Technology Reinvestment Project (TRP) and their combined appropriations for fiscal year 1993 total about $480 million (see Summary Table). TRP programs would be allotted just a fraction of the initiative's total funding. But these federal awards are a key component of efforts to orient defense companies toward more dual-use production.

In the past, most federal research and development has been mission-oriented; it has supported the goal of, say, building military aircraft or mapping genes. But TRP and other programs proposed by the Clinton Administration have much broader aims; they are designed to encourage organizations to channel their research into commercial products and to improve the productivity of U.S. companies. They signal a distinct policy shift from previous administrations. It is a shift that promises rewards but also entails risks.

PLANS FOR CARRYING OUT TRP

TRP is being administered by an interagency group known as the Defense Technology Conversion Council. The council is composed of agencies within the Departments of Defense, Energy, Transportation, and Commerce; the National Science Foundation; and the National Aeronautics and Space Administration. The White House is also actively involved. For fiscal year 1993, the Advanced Research Projects Agency (ARPA), an organization within the Department of Defense, has the responsibility of managing the TRP programs.

SUMMARY TABLE FISCAL YEAR 1993 FUNDING FOR THE TECHNOLOGY REINVESTMENT PROJECT (In millions of dollars)

Programs	Appropriation[a]
Technology Development	
Defense dual-use critical technology partnerships	95.2
Commercial-military integration partnerships	47.6
Regional technology alliances[b]	95.2
Defense advanced manufacturing technology partnerships	23.7
Technology Deployment	
Manufacturing extension	95.2
Dual-use assistance extension	95.2
Manufacturing Education and Training	
Manufacturing engineering education grant program	23.8
Manufacturing experts in the classroom	4.8
Total	480.7

SOURCE: Congressional Budget Office based on information from the Comptroller's Office of the Department of Defense.

a. Differs from previously published appropriation levels because of general and undistributed reductions in defense research, development, test, and evaluation appropriations.

b. Awards may also be used for technology deployment projects.

TRP programs will cover three areas:

- o Technology development;
- o Technology deployment; and
- o Manufacturing education and training.

Technology development programs will provide seed money to cultivate new dual-use technologies and explore their application to the civilian market, the military sector, or both. A typical development program might, for example, foster research into special materials for high-speed computer chips.

Technology deployment programs will help disseminate existing process and product technologies and provide information about effective business practices to companies that in the past have relied on defense sales. Deployment programs will focus particularly on firms with 500 or fewer employees. A project might, for example, develop electronic networks to disseminate information about methods of dual-use production.

Manufacturing education and training awards will support colleges and universities or consortia that develop more practical curricula in manufacturing engineering. Such programs could be used, for example, to help defray the cost of bringing more practicing engineers into the classroom on a temporary basis.

Although they vary widely in nature and scope, TRP programs share two common features: they encourage collaboration among federal agencies, private companies, universities, and not-for-profit organizations, and they usually require award recipients to bear at least half of the project's costs. The programs were designed in this manner to encourage communication among organizations that conduct research and development (R&D), and so that participants have a vested interest in a project's successful completion. The federal government may, however, end up paying more than half of the bill because in some cases recipients of TRP awards would be permitted to use other federal funds as part of their share of the cost.

METHODS FOR PROPOSAL AND SELECTION

Private companies and public groups can propose projects to be funded under TRP. The Defense Technology Conversion Council will solicit, evaluate, and select proposals and then distribute project management responsibilities to individual agencies that are expert in a particular technology or program type.

For fiscal year 1993, the council made a formal solicitation in May 1993, with proposals due in July and selections expected in September.

Evaluation criteria differ for technology development, technology deployment, and manufacturing education and training programs. Generally, however, proposals will be reviewed for their technical merit, the extent to which a successful project will advance U.S. national security and economic goals, and the likelihood that a project will achieve commercial practicability.

POTENTIAL BENEFITS AND RISKS

By cultivating dual-use technologies, TRP programs may offer important benefits. But they also bring with them the risks inherent in federal subsidies for private research and development.

Benefits

TRP programs may benefit national security by fostering the integration of defense and civilian industries. Arguably, certain defense equipment may be cheaper and more capable if it incorporates high-technology components that are available commercially. But military and civilian production have for the most part been treated as two distinct sectors in the U.S. economy. TRP programs may help bring more of the benefits of civilian technology to the military and, similarly, apply defense technologies to commercial products.

By promoting dual-use technology, TRP programs may also help maintain the base of companies that can produce defense equipment. TRP and other defense conversion initiatives are not likely to reduce significantly the layoffs that will take place over the next few years because of cutbacks in defense spending. The technology programs may, however, help retain some scientists and engineers who have key defense knowledge. And if TRP is successful in integrating military and civilian production more closely, it may even broaden the base of companies in defense production. This potential benefit is particularly important in a period when defense budgets are declining sharply while future threats to U.S. security remain highly uncertain.

Moreover, TRP makes up part of the Clinton Administration's new technology policy, which is aimed at increasing and improving research and development in the United States. TRP will emphasize investment projects that have many end-use applications and are beyond basic research but still in the preliminary stages of realizing their commercial potential. Some

analysts argue that the private sector may underinvest in research and development of this type if left to its own devices.

Advocates also contend that programs like TRP can help improve the competitive position of U.S. industries by transforming scientific discoveries into commercial products. Some analysts argue that countries that are the first to bring an innovation to market stand to gain more than their foreign competitors. Finally, by encouraging organizations to collaborate on R&D projects, TRP may help reduce duplication of effort, spread the risk of large research projects, and improve communication among research teams.

Risks

The Technology Reinvestment Project also brings with it some risks. Its programs emphasize collaboration, and joint research and development ventures could serve some socially useful purposes. But even carefully organized research consortia may not succeed; some analysts point out that many collaborative efforts during the 1980s concentrated on projects that were of low priority or suffered from vague objectives.

Critics of federal research and development programs also contend that the government is ill-equipped to pick "winners" and "losers" among proposed research projects. Part of the problem is that federal research and development programs can become politicized. Funding for projects can become entrenched politically, making them difficult to discontinue. Executive branch agencies may have political motives when they support funding for certain projects without competition. And the Congress sometimes specifies in detail how it would like R&D funds to be spent, effectively replacing the role of technical experts or a competitive review process.

For example, in the conference report accompanying the fiscal year 1993 defense appropriations bill, the Congress stipulated that nearly 25 percent of the value of TRP appropriations be earmarked for specific technologies or projects. At least for fiscal year 1993, the Defense Technology Conversion Council and the White House have agreed to award TRP funds competitively, as was stipulated in the project's authorizing language. However, some specific projects identified in the conference report may receive funding through technology programs other than TRP.

Because it is hard to pick winners and losers, it is all the more important to evaluate the projects to see if they are producing useful results.

But effective evaluation is difficult. Comprehensive measures of effectiveness are seldom used because considerable time must elapse before outcomes can be assessed. It is also extremely difficult to disentangle the effects of federal support from other factors that influence results. For example, it may be very hard to tell whether federal support in developing special materials for computer chips actually improves U.S. competitiveness in this fast-moving industry, or whether the industry would have invested in the technology itself without federal assistance.

The difficulty of evaluation, however, should not deter program managers from trying. If federally sponsored projects are not evaluated critically, costly programs that are difficult to discontinue could supplant other investments with greater social return. Although it is still young, the managers of the Department of Commerce's Advanced Technology Program are making a concerted effort to evaluate their program. TRP managers would do well to use it as a model.

ISSUES SURROUNDING IMPLEMENTATION

Even if the risks are avoided, TRP will realize its full potential only if managers can circumvent obstacles when carrying out the programs. Budgets for federal agencies that will manage TRP are growing significantly, causing concern about whether funds will be managed properly. Between fiscal years 1992 and 1993, for example, the budget of the Defense Department's Advanced Research Projects Agency is expected to rise by more than 40 percent in nominal terms when one includes the value of TRP funding and other dual-use technology programs. It has been alleged that ARPA has become less effective recently because it is understaffed, which could reduce the agency's ability to manage growing dual-use programs. ARPA, however, has a history of managing large budget swings by giving program managers substantial authority and by using the staff of military services and defense agencies as "agents" who oversee its contracts. Managers also plan to hire administrative support to handle the initial influx of TRP proposals and borrow personnel from federal agencies to conduct technical reviews.

TRP programs may also overlap other projects. Indeed, there is apparently topical overlap between TRP and continuing programs at various agencies. But program managers argue that TRP awards will in some cases augment rather than duplicate existing programs because, in their view, several well-designed technology projects are underfunded. A certain amount of redundancy may also be desirable in research and development programs.

Maintaining the private portion of cost sharing is another important issue. Almost all TRP programs require award recipients to bear part of the costs. This provision is designed to make sure that participants have a vested interest in a project's outcome and do not become too dependent on federal support. But in some cases, other federal funds can be used to make contributions to TRP projects, effectively reducing cost sharing. Program managers contend that they will try to minimize this problem by giving preference to proposals financed with the proposer's own cash.

THE FUTURE OF TRP

Because there are risks and obstacles in carrying out the programs, it may be useful to compare TRP with other federal policies that have similar goals. The reform of defense acquisition or federal procurement of civilian high-technology products, for example, could also prompt defense companies to diversify into civilian production and could break down barriers between their military and commercial divisions. Some analysts argue that tax credits for research and development may be a preferable policy because firms would select and initiate projects themselves. One should note, however, that it may be difficult to monitor the validity and effectiveness of such credits.

These policy options could be pursued along with TRP. But the Congress should also consider whether planned TRP programs are likely to address its goals more effectively than other policy options.

CHAPTER I

INTRODUCTION

During the Cold War, the U.S. defense industrial base developed some of the world's most advanced military technology and equipment. These efforts required large amounts of federal money and much of the country's science and engineering talent. But with the demise of the Soviet Union, many believe that U.S. national security interests can be protected with lower levels of defense spending. President Clinton has proposed that, by 1998, outlays in the national defense budget should fall to a level of about $228 billion, measured in 1993 dollars. Measured in those same dollars, defense outlays in 1990 stood at $332 billion, about 46 percent higher than the planned level for 1998. In 1992, defense outlays amounted to $308 billion, 35 percent more, a reduction of 11 percentage points in two years.

These substantial budgetary cutbacks provide both promise and uncertainty for the U.S. economy. According to Federal Reserve Chairman Alan Greenspan, the standard of living in the United States should ultimately increase because of the redirection of resources "that can be devoted to improving the nation's stock of productive physical and human capital...."[1] Those benefits are particularly likely to occur if money taken out of the defense budget is used to reduce the federal deficit or to fund public investments that increase productivity.

However, sharp cutbacks in defense spending also raise the question of whether, once the defense industrial base has finished contracting, the United States will be able to build the equipment it needs to face future military threats. The downturn in defense spending will also cause worker dislocations. The Congressional Budget Office estimates that the combination of the budgetary cuts proposed by former President Bush and the additional cuts recommended by President Clinton will result in eliminating 1.4 million defense-related jobs over the six-year period between 1992 and 1998.[2] Public and private employment in defense-related jobs, which in 1992 stood at about 5.5 million out of a total employed labor force of 119 million, will fall to about 4 million.

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1. Testimony of Alan Greenspan before the Senate Budget Committee, January 28, 1993.

2. Congressional Budget Office, "Effects of Alternative Defense Budgets on Employment," CBO Paper (April 1993).

In order to ease the transition of dislocated workers and the restructuring of industry, many policymakers have advocated federal funding for defense conversion. The term "defense conversion" is often used ambiguously. During the late 1970s and 1980s, some Members of Congress used the term to refer to legislation that would have required defense contractors to draw up alternative-use plans to diversify into civilian production. This legislation was based on the premise that individual plants could be converted so that their workers would be less vulnerable to declines in defense spending. Other people use the term more broadly to describe structural changes in the economy caused by downturns in military budgets. The expression is also used to describe changes that some analysts deem necessary for the defense establishment in this new era: widespread integration of commercial products and practices in military procurement.

The Clinton Administration sees a role for the federal government in easing the transition of defense workers to new jobs and in promoting economic growth to offset declines in military production. To facilitate conversion, President Clinton announced that he would like to spend over $19 billion on defense reinvestment and economic growth initiatives over the fiscal year 1993-1997 period (see Table 1). Within the Administration's fiscal year 1993-1997 plan, nearly 50 percent of the funds will finance high-technology programs that will be managed by agencies other than the Department of Defense (DoD). Of the remaining $9.8 billion, 54 percent will be used to retrain displaced defense workers and to provide assistance to communities hurt by defense cutbacks. The remainder will support defense research and development programs that orient defense contractors toward dual-use technologies--those with both civil and military applications--by cultivating their development and dissemination. The Administration refers to these DoD Dual-Use Technology Reinvestment programs in its proposals for the 1993-1997 period.

FOCUS ON THE TECHNOLOGY REINVESTMENT PROJECT

Technology Reinvestment Project (TRP) programs are eight initiatives designed specifically to promote dual-use technology. The programs were created as one part of Title IV of the Defense Conversion, Reinvestment, and Transition Assistance Act of 1992, which also provided assistance to defense workers and affected communities. These conversion initiatives were later incorporated in the fiscal year 1993 National Defense Appropriations Act.

TABLE 1. CLINTON ADMINISTRATION DEFENSE CONVERSION INITIATIVE
(Budget authority in millions of dollars, by fiscal year)

Programs	1993	1994	1995	1996	1997	1993-1997
Assistance to Defense Workers, Personnel, and Communities						
DoD personnel assistance and community support	693	693	693[a]	693[a]	693[a]	3,465
Department of Energy personnel assistance	25	100	0	0	0	125
Department of Labor displaced worker training	0[b]	300[c]	400[c]	400[c]	400[c]	1,500
Department of Commerce community diversification assistance	0	33	55	55	55	198
Subtotal	718	1,126	1,148	1,148	1,148	5,288
DoD Dual-Use Technology Reinvestment (Including TRP)[d]	927	890	890[a]	890[a]	890[a]	4,487
New Federal High-Technology Investments[e]	47	1,206	2,329	2,758	3,175	9,515
Total	1,692	3,222	4,367	4,796	5,213	19,290

SOURCE: Congressional Budget Office based on data from the Office of Management and Budget.

a. 1994 level--estimates for 1995, 1996, and 1997 will not be available until the Department of Defense (DoD) completes its comprehensive review of defense programs.
b. $75 million has been transferred in 1993 from DoD.
c. Portion of increase in job training that is expected to be used for displaced defense workers.
d. Includes the Technology Reinvestment Project, agile manufacturing, advanced materials partnerships, U.S.-Japan management training, electronics and materials initiative, small business innovative research refocused to dual-use technologies, and increases in other dual-use technology programs. Excludes broadened scope of allowable Independent Research and Development reimbursement.
e. Includes programs that the Clinton Administration claims will provide "direct conversion opportunities" (for example, Department of Energy industry partnerships and National Aeronautics and Space Administration civil aviation research) and 50 percent of programs that provide "some conversion opportunities" (for example, Department of Commerce programs for information highways, manufacturing, and advanced technology). Not included are increases for enterprise zones, community development banks, the National Science Foundation, highway programs, and the research and development tax credit.

TRP programs will award funds competitively to organizations that develop dual-use technologies, deploy existing technologies and transfer effective business practices to firms, or build and promote college and university curricula in manufacturing education. All eight programs require award recipients to share costs.

For fiscal year 1993, TRP programs are funded at $480 million (see Table 2). Under the Clinton Administration's proposals, funding for TRP programs may decline somewhat in the years beyond 1993.

Although TRP programs make up more than half of all 1993 funding for DoD Dual-Use Technology Reinvestment, the programs account for a relatively small share of the total funds that the Clinton Administration plans to spend on defense conversion in the 1993-1997 period. Other programs would provide benefits to former defense workers and to defense firms. During the 1993-1997 period, the largest share of total funding would support federal investments in high technology run by agencies other than the Defense Department. Although the degree of benefit is not clear, the Clinton Administration claims that programs falling within this category--such as civilian aviation research or information highways--will offer jobs for former defense employees and conversion opportunities for defense contractors.

Defense conversion funds designated for personnel and community assistance should benefit former employees and, to a limited degree, defense firms. For example, the Economic Development Administration of the Department of Commerce will distribute funds to state and local governments, the communities of which are affected by sudden and severe economic dislocations. Grants may be used in ways that could benefit companies, including developing economic plans, establishing revolving loan funds for local businesses, financing employee buyouts of companies, and financing other services that encourage business development. The federal government does not directly support the conversion efforts of firms through these programs, but state and local governments have the discretion to do so.

Despite their small share of funding, TRP programs remain a key component of the Administration's plan to promote more dual-use production. Analyzing them also provides insight into the risks and rewards of other federal investments in defense conversion.

TABLE 2. TECHNOLOGY REINVESTMENT PROJECT FUNDING
(In millions of dollars)

Programs	Fiscal Year 1993 Appropriation[a]	Awards in Fiscal Year 1993[b]
Technology Development		
Defense dual-use critical technology partnerships	95.2	81.9
Commercial-military integration partnerships	47.6	42.1
Regional technology alliances[c]	95.2	90.5
Defense advanced manufacturing technology partnerships	23.7	23.5
Technology Deployment		
Manufacturing extension	95.2	87.9
Dual-use assistance extension	95.2	90.8
Manufacturing Education and Training		
Manufacturing engineering education	28.6[d]	43.6[e]
Manufacturing managers in the classroom	d	4.6
Total	480.7	472.1

SOURCE: Congressional Budget Office based on data from the Comptroller's Office of the Department of Defense and the Advanced Research Projects Agency.

a. Differs from some published values for fiscal year 1993 because of general and undistributed reductions in research, development, test, and evaluation appropriations.

b. Advanced Research Projects Agency, *Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance* (March 10, 1993). Program values exclude a total of $7.2 million in small business innovative research (SBIR) set-asides, but the SBIR value is included in the total.

c. Awards may also be used for technology deployment programs.

d. Includes funding for both the Manufacturing Engineering Education Program and Manufacturing Managers in the Classroom.

e. Includes $20.1 million appropriated in fiscal year 1992 but not released by the Office of the Secretary of Defense until early 1993.

TABLE 3. MEMBERS OF THE DEFENSE TECHNOLOGY CONVERSION COUNCIL

Federal Department or Independent Agency	Council Representative
Defense	Director, Advanced Research Projects Agency
Commerce	Director, National Institute of Standards and Technology
Energy	Assistant Secretary, Defense Programs
Transportation	Assistant Secretary, Policy
National Science Foundation	Director
National Aeronautics and Space Administration	Associate Administrator, Office of Advanced Concepts and Technology

SOURCE: Department of Defense.

FINANCING AND ADMINISTRATION OF TRP

For fiscal year 1993, funds for TRP will come from the budget of the Department of Defense. An interagency council will administer the TRP, led by the Advanced Research Projects Agency (ARPA) of the Defense Department.[3] Other agencies that will participate include the Commerce, Transportation, and Energy Departments, the National Science Foundation, and the National Aeronautics and Space Administration (see Table 3).

In the years beyond 1993, an increasing share of TRP funding may be financed and administered by agencies other than the Defense Department. The Defense Conversion Commission--a group established by the Congress to assess policies related to defense conversion--noted that the Budget Enforcement Act of 1990 (BEA) played an important role in financing defense conversion programs within the fiscal year 1993 DoD budget.[4] One of the BEA's provisions set annual ceilings on three categories of federal discretionary spending through fiscal year 1993, namely, national defense,

3. As recommended by the Congress, the Defense Advanced Research Projects Agency (DARPA) recently reverted to ARPA, the name by which it was known until 1972.

4. Defense Conversion Commission, *Adjusting to the Drawdown* (December 31, 1992), p. 72.

international affairs, and domestic programs. For fiscal year 1993, discretionary spending for domestic programs was near its BEA limit, whereas defense spending was below its cap. As a result, in part, the Congress funded defense conversion legislation in the defense budget. After fiscal year 1993, annual ceilings will only apply to total discretionary spending, leaving the Congress more freedom to finance defense conversion programs in other agencies.

CHAPTER II

FISCAL YEAR 1993 PLANS FOR CARRYING OUT THE TECHNOLOGY REINVESTMENT PROJECT

Although the Technology Reinvestment Project administers eight distinct statutory programs, the programs have the common goal of encouraging the integration of military and civilian research, development, and manufacturing. (See Table 4 for a summary of program features and Appendix A for more information.) Rather than simply administering these programs simultaneously, managers hope that the proposals they select for TRP awards will form a single, coherent conversion effort.

CHARACTERISTICS OF TRP PROGRAMS

The TRP programs fall into three categories of activity:

- Technology development programs are intended to create new technologies that have both civil and military uses, or to encourage technologies developed for one market sector to be applied to the other;

- Technology deployment programs disseminate existing product and process technologies and provide information about effective business practices through traditional extension services or activities that link technology developers with providers of extension services; and

- Manufacturing education and training programs are intended to strengthen the work force by providing educational opportunities for defense professionals and encouraging more practical and integrative approaches to engineering education.

Technology Development Programs

Three of the eight programs within TRP are oriented primarily toward technology development: Dual-Use Critical Technology Partnerships, Commercial-Military Integration Partnerships, and Defense Advanced Manufacturing Technology Partnerships. A fourth TRP program, Regional

TABLE 4. PROGRAMS OF THE TECHNOLOGY REINVESTMENT PROJECT

Programs	Mission	Who May Apply?
Dual-Use Critical Technology Partnerships	Technology development	Two or more eligible firms or a nonprofit organization formed by two or more eligible firms. Others may participate.
Commercial-Military Integration Partnerships	Technology development	One or more eligible firms or one or more nonprofit organizations formed by two or more eligible firms. Others may participate.
Defense Advanced Manufacturing Technology Partnerships	Technology development	Two or more eligible firms or a nonprofit organization formed by two or more eligible firms. Others may participate.
Regional Technology Alliances	Technology development or technology deployment	One or more eligible firms plus a sponsoring agency such as a state or local government agency. Others may participate.
Defense Manufacturing Extension Program	Technology deployment	Manufacturing extension programs of regions, states, local governments, or nonprofit organizations.
Defense Dual-Use Assistance Extension Program	Technology deployment	Federal, state, and local government agencies, regional entities, private groups, or nonprofit organizations.
Manufacturing Engineering Education Grant Program	Manufacturing education and training	Institutions of higher education or consortia of institutions of higher education. Eligible firms may participate.
Manufacturing Managers in the Classroom	Manufacturing education and training	Institutions of higher education. Eligible firms may participate.

TABLE 4. CONTINUED

Percentage of Private Cost Sharing	Other Federal Funds Allowed?	Maximum Period of Performance?	Fiscal Year 1993 Funding (In millions of dollars)
50 percent (less at the discretion of the Secretary of Defense)	No	No	81.9
50 percent in first year, 60 percent in second year, and 70 percent in third through fifth years	Yes	Five years	42.1
50 percent (less at the discretion of the Secretary of Defense)	No	No	23.5
50 percent	No	Six years	90.5
50 percent	No	Five years	87.9
50 percent in first year, 60 percent in second year, and 70 percent in subsequent years	Yes	No, but funding not authorized beyond September 30, 1998	90.8
50 percent	Yes	No	23.5 (plus 20.1 in fiscal year 1992 funding)
50 percent	Yes	No, but two-year minimum period of performance	4.6

SOURCE: Congressional Budget Office based on information from the Advanced Research Projects Agency.

Technology Alliances, may include some technology development projects and some technology deployment projects.

Three of these technology development partnership programs have similar aims, but differ slightly in their focus. The Dual-Use Critical Technology Partnership program is the broadest; its awards will be used to develop a wide variety of dual-use technologies. Commercial-Military Integration Partnerships will provide federal funds to develop civilian technologies that can enhance the capabilities of military equipment--so-called spin-ons. Technologies to enhance dual-use manufacturing processes are the focus of Defense Advanced Manufacturing Technology Partnerships. The Regional Technology Alliance program will provide federal funds to regional organizations that assist in developing applications of critical technologies--the term used to describe fields considered most important for U.S. national security and economic growth (see Appendix B).

All of these technology development programs are designed so that private businesses must collaborate or form alliances with other organizations. In most cases, profit-oriented applicants for TRP awards must be eligible firms--that is, companies that conduct a significant amount of their research, development, engineering, and manufacturing activities in the United States, or other companies if U.S. citizens hold majority ownership or control. Foreign-owned firms may be considered eligible if their parent companies are incorporated in countries in which the government encourages the participation of U.S.-owned firms in research and development (R&D) consortia that are publicly funded, as judged by the Secretary of Commerce.[1] One of the criteria by which proposals will be evaluated, however, is the impact a proposal is expected to have on the U.S. economy.

A Critical Technology Partnership award is an example of the type of program that would be funded within the technology development portion of TRP. The Advanced Research Projects Agency of the Department of Defense announced this award in April 1993, and it is financing the project with appropriations from fiscal year 1992.

Under the program, ARPA will match $5 million in private funding to develop special materials for advanced dynamic random access memory (DRAM) chips. DRAMs are the most widely used type of semiconductor device and have both civil and military applications. The materials developed for this project will be used to produce chips that can store 256 million bits

1. Advanced Research Projects Agency, *Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance* (March 10, 1993), p. 2-7.

of information--16 times as many as today's most widely selling DRAM chips. A consortium composed of a materials manufacturer, three chip producers, a semiconductor equipment maker, and a university will conduct the R&D. The organizations involved are Advanced Technology Materials Inc., IBM, Texas Instruments, Micron Technology, AG Associates, and North Carolina State University, respectively.[2]

Technology Deployment Programs

Two TRP programs are intended primarily to disseminate technology and teach effective business practices. Awards under the Defense Manufacturing Extension Program will provide financial support to extension services established by state and local government agencies or nonprofit organizations, or may link existing extension services so that they can share information about technologies and better business practices. Projects within the category of conventional manufacturing extension services will target small businesses--those with 500 or fewer employees.

The scope of the Defense Dual-Use Assistance Extension Program is quite broad. Funds from this program can be used for such activities as helping firms adopt civilian management and marketing practices, identifying dual-use products into which companies can diversify, promoting exports, or helping locate potential suppliers and subcontractors.

The following hypothetical Defense Manufacturing Extension Program award illustrates the way a TRP technology deployment program would work:

> Suppose that a city in the center of the United States--call it Big City, East Dakota--is a metropolitan area with about 5,000 small businesses, 40 percent of which have contracts with the Defense Department. East Dakota already provides $500,000 annually to Big City Community College, which uses the funds to create a facility that demonstrates how small businesses can retrofit machine tools with numerical control technology. An evaluation of the program reveals, however, that few of the facility's current clients are defense contractors or suppliers. East Dakota and the community college decide to submit a TRP proposal to initiate an outreach program and provide specialized consultation services to small firms that have been suppliers to the Defense Department. In particular, the college contacts several local suppliers of aircraft engine parts and

2. John Burgess, "U.S. Gives $5 Million for Chip Project," *The Washington Post*, April 13, 1993.

finds that the companies need help evaluating the equipment on their shop floors to see if it is suitable for retrofitting with numerical control technology. Some of the companies would like to supply more parts to the commercial aircraft industry, but they need technical assistance to decide what new equipment investments they should make. The state contributes $500,000 to finance the TRP program and the college donates compensation for the time of its personnel. Federal funds are used to pay 50 percent of costs for the extension service over a five-year period.

Manufacturing Education and Training Programs

The final two TRP programs--the Manufacturing Engineering Education Grant Program and Manufacturing Managers in the Classroom--focus on educating the next generation of engineers and integrating military and civilian engineering practices. Institutions of higher learning or consortia of colleges and universities may win awards for a wide variety of projects that build or enhance programs in manufacturing engineering. In particular, the council that is set up to manage TRP programs hopes to encourage the involvement of industry representatives in teaching and curriculum design.

A Manufacturing Education and Training Program award might help establish a fellowship program for engineers who have been laid off because of defense cutbacks. For example:

Eastern University is located in a community where defense-related jobs account for more than 20 percent of local employment. Declines in defense spending have hit area contractors hard, and many companies are reducing their work forces. With a two-year, $400,000 TRP matching grant, Eastern University creates a fellowship program in its engineering department for defense engineers who would like to return to school for an applied master's degree. Students receive tuition waivers and support for living costs while pursuing their degrees. Eastern University agrees to give students credits for their work experience, but they must also take academic coursework to update their skills and participate in seminars that are oriented toward practical engineering applications.

TRP Program Characteristics

All TRP programs share some general characteristics, although the programs differ in detail. For example, all TRP programs emphasize collaboration among federal agencies, groups of businesses, nonprofit organizations, federal laboratories, or colleges and universities. Each program, however, has different criteria for deciding what specific groups or organizations may apply for an award (see Table 4). Most technology development programs require that applicants include at least one eligible firm or a nonprofit research organization formed by eligible firms. Technology deployment programs will generally support extension services run by regional groups, state or local government agencies, or nonprofit organizations. Applicants for manufacturing education and training awards must be institutions of higher education. Although the TRP carefully specifies who official applicants must be, other entities are not precluded from participating in a project.

Almost all TRP programs require that award recipients share part of the costs, usually at least 50 percent. Cost sharing is an important characteristic of the TRP since it ensures that participants have a vested interest in a project's outcome. Nonetheless, it is important to note that the federal government may ultimately bear the majority of project costs. In some programs, such as Commercial-Military Integration Partnerships, funds from federal agencies other than the Defense Department may be counted as part of a recipient's contribution. Costs associated with independent research and development projects--a form of research project funded in part by the Defense Department--may also be included as part of the recipient's share of costs. Reduced taxes could also offset the private share of funding; an award recipient's share of project costs may qualify for research and experimentation tax credits.

By tapping such sources of funding, the benefits of cost sharing--ensuring that participants have a vested interest in a project's outcome--may not be realized. To avoid this, program managers note that they will consider the nature of matching funds when selecting recipients of TRP awards. For example, if a consortium claims that other federal funds constitute part of its share of costs on a technology development project, TRP evaluators may conclude that the proposal is less likely to bring the technology to the market than a proposal that is supported by a consortium's own cash.

TRP programs also vary in their limits on the number of years during which a project may receive support. Three TRP programs have sunset clauses, and five do not (see Table 4). Sunset clauses are designed to ensure

that specific projects do not become "entitlements" that are renewed annually without critical evaluation.

The three TRP programs that have sunset provisions follow a precedent established by some other federal R&D programs. The Advanced Technology Program run by the National Institute of Standards and Technology (NIST) is one example; awards made to an individual firm can be used to cover project costs over a period of up to three years.

HOW PROJECTS WILL BE SELECTED AND MANAGED

Overall, TRP will be managed by an interagency group known as the Defense Technology Conversion Council, which will review applications and award nearly $472 million. The council was formed under a Memorandum of Understanding signed in March 1993, and for fiscal year 1993, the Director of ARPA will serve as the council's chairman and its DoD representative. Other participants include the Assistant Secretary of Energy for Defense Programs, the Director of NIST, the Director of the National Science Foundation, the Associate Administrator of the Office of Advanced Concepts and Technology of the National Aeronautics and Space Administration, and the Assistant Secretary for Policy of the Department of Transportation.

Selection and Contracting

The first step in selecting and managing the TRP programs is publicizing the nature of available federal funding. The Defense Technology Conversion Council made an informational brochure about TRP available to the public in March 1993.[3] TRP organizers also provided information about the program with a toll-free telephone number, over Internet, and through a series of briefings for potential applicants across the country during April and May. The TRP was initially announced in mid-March and a formal solicitation was published in mid-May, with proposals due on July 23.

Once proposals are received, they will be evaluated using a system of weighted criteria that differ for each category of project: technology development, technology deployment, and manufacturing education and training. Awards of fiscal year 1993 funds are expected to be announced in the fall.

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3. Advanced Research Projects Agency, *Program Information Package.*

Awards may take the form of grants, cooperative agreements, contracts, or other transactions such as loan or joint funding agreements and reimbursable arrangements. The council does not plan to use contracts extensively, since many TRP projects are intended to advance the state of the art rather than to develop a specific product or service. Grants may be used when the administering agency is expected to play a limited role in a project. However, ARPA anticipates that it will use its authority to enter extensively into other transactions (also called agreements).

Agreements are financial instruments available to ARPA that fall outside the legal requirements of the Federal Acquisition Regulation (FAR). Since 1989, ARPA has had authority to use agreements when it is facilitating R&D rather than acquiring products or services. Because the FAR does not apply, agreements allow award recipients to retain intellectual property rights over project results.[4] Proposers are also permitted to use independent research and development expenses as part of their private share of costs, and are subject to auditing requirements less stringent than those for other financial instruments--a feature that private companies prefer, but one that has led to a few difficulties in other federal programs.[5]

Participants may pay their share of project costs either in cash or in kind. In-kind contributions may include compensation for personnel; the prorated fair rental value of land, equipment, and software used for a project; proprietary technology; and some categories of independent research and development. Recipients of awards will be required to submit quarterly technical progress reports, an annual audit that meets generally accepted accounting practices, and financial reports accompanying requests for federal payment. These requirements are more like those found in private industry than in most defense programs, which often ask for special accounting systems and audits.

Managing the Projects

Once projects are selected, the Defense Technology Conversion Council will divide responsibilities for contract administration among relevant agencies. For example, many of the manufacturing extension projects are likely to be

4. Rights for government use of the technology will be negotiated between ARPA and award recipients. "March-in" rights will be maintained for each award. These allow the federal government to take over intellectual property rights in cases where an award recipient has not commercialized the technology within a specific period of time after the agreement is complete.

5. General Accounting Office, *Commercial Use of Space*, GAO/NSIAD-91-142 (May 1991).

administered by NIST's Manufacturing Extension Partnerships program. It is not yet clear whether this plan will include a formal transfer of fiscal year 1993 funding from the Defense Department to other council agencies or whether the other agencies will simply act as project managers for DoD's ARPA.

The use of an interagency council to solicit, evaluate, and select projects jointly is unprecedented. The practice is, however, consistent with federal policy for managing these types of activities. Broadly, the Office of Science and Technology Policy relies on the Federal Coordinating Council on Science, Engineering, and Technology and its working groups to coordinate programs among agencies. At a lower level, specialists from one agency are often asked to review proposals for programs sponsored by others and thereby learn what federal R&D projects are under way. The Defense Technology Conversion Council is a more direct means of coordinating federal R&D efforts.

Arguably, recent technology initiatives such as that in high performance computing demonstrate that an interagency structure can be used effectively.[6] But it remains to be seen whether the council will be able to maintain the degree of cooperation among agencies that is needed to carry out TRP programs effectively.

Small Business Innovative Research

A share of all fiscal year 1993 TRP funds will be set aside for small business innovative research (SBIR) awards. The Congress established the SBIR program in 1982 and it applies to all federal agencies with annual R&D budgets larger than $100 million. The program's aim is to promote the commercialization of research by small firms--those with 500 or fewer employees--and to help them compete for federal awards. Under the fiscal year 1993 Defense Authorization Act, the Congress increased the percentage of defense R&D funding that must be set aside for SBIR from 1.25 percent to 1.5 percent in fiscal year 1994 and by an additional one-quarter of one percent every year for the following four years. Under the law, 2.5 percent will be set aside in fiscal year 1998 and thereafter. These legal guidelines also apply to TRP programs.

Although not required by law until fiscal year 1994, the Clinton Administration has proposed setting aside 1.5 percent of fiscal year 1993 TRP funding--$7.2 million--for SBIR awards to be conferred in a complementary

6. Dorothy Robyn, "Orchestrating Federal R&D," *Technology Review*, vol. 96, no. 5 (July 1993), pp. 66-68.

solicitation. This portion of the TRP would be administered separately from other defense SBIR funds. In addition, the Administration hopes to redirect some $85 million in fiscal year 1993 Defense Department SBIR funds toward research in dual-use technologies.

SBIR projects are divided into phases. Phase I awards confer up to $100,000 and sponsor studies of the scientific or technical feasibility of a research idea. If results of a Phase I project merit it, a Phase II study may be funded to undertake research that results in a well-defined product within a 24-month period. In the third phase of the program, participants are expected to bring their new technology to the market, normally without additional SBIR funding.

For fiscal year 1993 TRP awards, SBIR proposals are limited to Phase I studies of the development of new dual-use technologies or the application of military technologies to the commercial sector. Proposals are limited to Phase I because in the past the SBIR program has not supported much research on dual-use technologies. Cost sharing is not required for Phase I TRP studies because program managers believe that too few small businesses would be able to participate. Appropriations for dual-use technology programs in the future may be used to finance Phase II research, and small businesses with successful TRP projects will even be encouraged to apply for Phase III funding on a cost-shared basis.

PROPOSED FUNDING FOR FISCAL YEAR 1994

What is likely to happen to funding for TRP programs in the years beyond 1993? For fiscal year 1994, the Administration has proposed reducing DoD Dual-Use Technology Reinvestment programs by a net of $37 million (see Table 5). Dual-Use Critical Technology Partnerships and Advanced Manufacturing Technology Partnerships would expand by $53 million and $6 million, respectively, but most other TRP programs would shrink.

TRP technology deployment programs fall under the category of "manufacturing technology extension" (see Table 5). One deployment program, the Defense Manufacturing Extension Program, was singled out by the Defense Conversion Commission as an example of an initiative that duplicates efforts of other federal agencies.[7] The Clinton Administration plans to use fiscal year 1993 funding for this category to support projects over a two-year period, and it is likely to propose moving funding for most manu-

7. Defense Conversion Commission, *Adjusting to the Drawdown* (December 31, 1992), p. 71.

TABLE 5. DOD DUAL-USE TECHNOLOGY REINVESTMENT PROGRAMS
(In millions of dollars)

Programs	Fiscal Year 1993 Funding	Fiscal Year 1994 Funding[a]
Reinvestment		
Dual-use critical technology partnerships[b]	95	148[c]
Commercial-military integration partnerships[b]	48	35
Regional technology alliances[b]	95	85
Advanced manufacturing technology partnerships[b]	24	30
Manufacturing engineering education[b]	29	20
Agile manufacturing/enterprise integration	29	20
Advanced materials partnerships	29	24
U.S.-Japan management training	9	5
Subtotal	357	367
Manufacturing Technology Extension[b,d]	190	25
Other Programs Transferred to ARPA[e]	24	0
Electronics and Materials Initiatives[f]	271	248
Additional Dual-Use Initiatives[g]	0	89
SBIR Refocused to Dual Use	85	161
Total	927	890

SOURCE: Office of Management and Budget.

a. Proposed.
b. TRP program.
c. Includes DoD Software Initiative Technology.
d. Includes funding for both the Manufacturing Extension Program and the Dual-Use Assistance Extension Program. Fiscal year 1993 funding supports projects over a two-year period.
e. Projects transferred to ARPA for execution in fiscal year 1993.
f. Includes projects on high-definition systems, optoelectronics, metal matrix and ceramics, diamond substrates, multichip modules/high-temperature superconductivity, battery technology, multichip modules, advanced lithography, and composite materials manufacturing.
g. Changes in funding from fiscal year 1993 for ongoing ARPA programs, including SEMATECH, basic research, high-performance computing, infrared focal plane array, manufacturing technology initiatives, electronics modules, software engineering, materials processing, electronics processing, advanced simulation, high-temperature superconductivity, and intelligence system software.

facturing extension programs to the Department of Commerce budget after fiscal year 1994. The issue has not yet been debated by the Congress, however, and it remains to be seen who will fund manufacturing extension services.

The Clinton Administration proposed decreasing funding for electronics and materials initiatives in fiscal year 1994 by $23 million. Within these initiatives, high-definition systems and advanced lithography programs would experience declines, but budgets for optoelectronics, battery technology, and multichip modules would increase. Other continuing ARPA programs that are dual-use in nature, including those for high-performance computing, electronics modules, high-temperature superconductivity, and intelligence system software, would receive an $89 million increase. Under the proposal, dual-use SBIR funding would expand by $76 million.

CHAPTER III

POTENTIAL REWARDS, RISKS, AND IMPLEMENTATION ISSUES

Defense conversion research and development programs like the Technology Reinvestment Project are intended to benefit national security and could also help bolster the pace of economic growth in the United States.

NATIONAL SECURITY BENEFITS

TRP programs might help maintain the industrial base that can produce defense equipment. They might also hold down the cost of that equipment.

Maintaining the Industrial Base

Military and civilian production have been treated as two distinct sectors in the U.S. economy. Even defense contractors who produce both defense and civilian goods often keep their divisions widely separated. There are several reasons for this. Unique cost accounting standards, auditing requirements, and regulations for dealing with classified information are expensive and may deter commercial firms from selling to the Department of Defense. Military product standards may be so specialized that they render an item too costly to compete with civilian substitutes. And contractors are usually required to turn ownership claims on technical data over to DoD, which may keep them from using military technology for civilian purposes.

As military spending decreases, integration of civilian and military production becomes increasingly important. Otherwise, only a few companies would remain in the defense business and retain the capability of producing sophisticated military weapons. That would be a serious problem if U.S. security were threatened, requiring a rapid buildup of military forces.

What must be done to help integrate military and civilian production? Both the Congress and the Clinton Administration recognize the importance of procurement reform because it would eliminate such barriers as unnecessary specialization to produce DoD weapons. In its fiscal year 1991 Defense Authorization Act, the Congress directed DoD to review its procurement laws and make recommendations to streamline the acquisition process. The resulting report, informally known as the Section 800 study, recommends waiving special accounting standards for most transactions

involving products that are available in the civilian market. It also recommends expediting procedures for contracts of $100,000 or less.[1] The Clinton Administration's new Deputy Secretary of Defense, William Perry, hopes to make commercial standards commonplace in defense procurement unless the military services can, in certain cases, justify specifications. Perry is a strong proponent of procurement reform because he believes it will reduce acquisition costs and allow DoD to buy more or better quality goods with what is likely to be a limited defense budget.[2]

The Clinton Administration also believes that R&D programs like TRP can help maintain the defense industrial base by fostering integration of military and civilian production. During Congressional testimony, one prominent executive argued that some defense companies are unable to raise the capital they need to diversify into civilian markets because many contractors failed when they tried to produce commercial products during the 1970s. Without such diversification, some firms might not remain in business and their defense expertise would be lost. TRP is one means of providing capital, as long as contractors have competitive ideas for civilian products and are willing to risk some of their own money. Although defense firms are skilled at advancing the state of the art in certain technologies, the business environment in which their managers operate is quite different from that of the civilian sector; for one thing, there is less emphasis on lowering unit production costs.[3] Defense-oriented firms may also be unfamiliar with civilian marketing practices. TRP supporters believe that, because award recipients must explore the civilian applications of a technology and invest some of their own money, the program will help defense companies adjust to the commercial environment. That way, they would remain in business producing both defense and civilian goods.

Will TRP be able to help maintain a substantial industrial base that DoD can draw upon? Such a strategy will not work for all types of equipment; many major weapon platforms are highly specialized. To quote

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1. Department of Defense, *Streamlining Defense Acquisition Laws*, Report of the Acquisition Law Advisory Panel to the United States Congress (January 1993).

2. "Meet Mr. Procurement Reform," *Washington Technology*, vol. 8, no. 3 (May 6, 1993), pp. 5, 10. Perry also served as chairman of the Carnegie Commission on Science, Technology, and Government's Task Force on National Security, which recommended procurement reform in its report, *New Thinking and American Defense Technology* (August 1990).

3. Murray Weidenbaum, *Small Wars, Big Defense: Paying for the Military After the Cold War* (New York: Oxford University Press, 1992), p. 52.

a chairman of a major defense contractor, "There's no such thing as a dual-use tank or a dual-use submarine."[4]

Dual-use production may, however, help maintain portions of the defense industrial base. Some components, such as microelectronics and communications equipment, could be incorporated in both defense and civilian products. Production of these components is quite different from the process by which prime military contractors integrate complex systems. Therefore, as Defense Department officials have acknowledged, programs like TRP are more likely to benefit sub, rather than prime, contractors.[5]

Maintaining Weapon Quality at Lower Cost

TRP programs might also help to maintain the high capability of military weapons while keeping costs reasonable. Some observers maintain that there has been a shift in the flow of benefits between military and civilian research and development. In the postwar era, federal R&D spending largely took the form of support for (1) basic research at federal laboratories and universities, and (2) mission-oriented applied R&D on such investments as military weapon systems, civilian space vehicles, and medical research. Defense by far accounted for the bulk of federal R&D spending during the Cold War and still makes up nearly 60 percent today. Analysts agree that military R&D benefitted the civilian economy through technology spin-offs, such as numerical control of machine tools, microwaves, and computer software. In these cases, the Defense Department invested in technologies that led to or coincided with civilian applications and strong commercial demand.[6]

In some cases, the direction of the benefits may have reversed.[7] Many civilian technologies may be less expensive than comparable military products, and some defense equipment could be made more capable by incorporating commercially available high-technology products called spin-ons. For example, the acquisition cycle for military aircraft can last up to 20 years.

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4. William Anders, chairman of General Dynamics Corporation, as quoted in John Mintz, "Clinton to Announce Defense Plan," *The Washington Post*, March 11, 1993, p. D11.

5. Testimony of John M. Deutch, Undersecretary of Defense, Acquisition and Technology, before the Subcommittee on Defense, Senate Committee on Appropriations, May 27, 1993.

6. Civilian markets may benefit from military demand for a high-technology good when its production is characterized by economies of scale. For more on this, see C. R. Neu, *Defense Spending and the Civilian Economy* (Santa Monica, Calif.: RAND, October 1990).

7. John Alic and others, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, Mass.: Harvard Business School Press, 1992).

During such a period, the microelectronics used in most commercial devices would have long since become obsolete. If companies producing DoD weapons freeze aircraft designs using microelectronics applicable solely to military use, and the planes are not deployed in large numbers for many years, they may be fielded with technology that is old by commercial standards.

TRP programs may help to keep the capability of weapons up to date and hold down costs by bringing about greater integration of military and commercial production. With dual-use components, weapons could be updated as improvements in microelectronics and other technologies become available commercially. Similar updates might not be feasible, or might be exorbitantly expensive, under policies that have led to strict separation of military and civilian production.

BOLSTERING ECONOMIC GROWTH

In addition to providing national security benefits, some policymakers and analysts believe that federal support for TRP programs and similar R&D spending contributes to the growth of the U.S. economy and standard of living.[8] Indeed, the Clinton Administration hopes that by investing in programs like TRP, the federal government will stimulate economic growth and improve the competitive position of U.S. industries.[9] Some advocates of a more activist role in technology development also point to foreign governments' R&D subsidies as an argument for federal support in the United States. The pace of technological change is rapid, and it is argued that countries that are able to develop innovations first can derive continued commercial benefits from them.[10]

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8. The Congressional Budget Office has produced many studies that analyze the issue of federal support for R&D in more detail. See, for example, *The Benefits and Risks of Federal Funding for Sematech* (September 1987), *Using Federal R&D to Promote Commercial Innovation* (April 1988), *Using R&D Consortia for Commercial Innovation: SEMATECH, X-Ray Lithography, and High-Resolution Systems* (July 1990), and *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy* (July 1991).

9. President William J. Clinton and Vice President Albert Gore, Jr., *Technology for America's Economic Growth, A New Direction to Build Economic Strength* (February 22, 1993).

10. For a review of the economic literature that discusses this argument, see Congressional Budget Office, "Targeting Emerging-Technology Industries," CBO Paper (March 1991).

Countering Incentives to Underinvest

How might TRP and other programs like it benefit the economy? One way relates to the nature of technological discoveries and information. When an innovation is introduced, it is difficult for the discoverer to reap all of the rewards. Competitors can derive or imitate the technology at a much lower cost than the original investment. Society often gains more than the innovator is able to recover through product sales or licensing. Because of this phenomenon, there is an incentive to wait for the innovations of other firms and, as a society, to underinvest in R&D.

Most economists believe that federal support for basic R&D is justified because projects financed by the private sector that have lower apparent returns would result in too little investment. More contentious, however, is the degree to which the federal government should support applied R&D programs--such as TRP--as projects move closer toward commercial products and processes.

Some analysts maintain that U.S. firms have been less effective than foreign competitors at converting scientific discoveries into commercial products.[11] Precompetitive technologies--those that are beyond basic research, but not yet developed enough to be brought readily to the commercial market--are a key step in transforming discoveries into products. Firms may not spend enough on this stage of R&D because it is less costly to imitate other, already developed technologies, or because there is too long a lag until they see a return on their investment.

The technology development programs within TRP emphasize these precompetitive technologies. Other TRP programs emphasize the dissemination of existing technologies--particularly manufacturing processes--because of the perception that U.S. businesses have been too slow to adopt innovations. By incorporating these features into the TRP and requiring award recipients to share project costs, advocates believe they can develop technologies of military importance, bolster U.S. economic performance, and avoid the pitfalls of industrial policy.

11. See a report by the private Council on Competitiveness, *Gaining New Ground: Technology Priorities for America's Future* (Washington, D.C.: Council on Competitiveness, March 1991).

Emphasizing Collaborative R&D

Most TRP programs are designed to promote collaboration that may benefit society. The typical TRP program is set up so that combinations of private companies, not-for-profit organizations, federal laboratories, state and local agencies, or institutions of higher learning must work together. Analysts believe that the financial resources needed to develop technologies that are far from becoming commercial products are often beyond the means of an individual firm, either because of the scale of the research project or its riskiness.[12] Because costs are shared, joint ventures in research can permit members to pool their financial resources and lower their individual R&D costs. Collaboration may also prompt firms to share other resources such as personnel, and may encourage members to develop technical standards so that they can share information with one another.

Although this view may not be widely accepted, some economists also contend that, since benefits are shared, collaboration can reduce the incentive to imitate the innovations of others and can increase investment in R&D. Other economists, however, argue that cooperative projects among firms that are direct competitors can actually lead to lower R&D investment.[13]

Collaborative R&D may also prevent companies from duplicating research efforts. Some overlap is inevitable as firms tailor a technology to suit their needs. But technologies might be developed at lower costs if companies cooperated with one another and assigned specific research tasks to partners who have expertise in those areas.

Finally, collaborative R&D may in some cases promote better communication among suppliers and users of a technology, or help disseminate research results more widely. For example, a 1990 study found that at the time, one of the clearest benefits of SEMATECH--a consortium of semiconductor and computer manufacturers that receives half of its funding from the federal government--was strengthened lines of communication between producers and users of semiconductor manufacturing equipment. By gaining a better understanding of the business plans of their clients,

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12. Murray Weidenbaum, "Sponsoring Research and Development," *Society*, vol. 29 (July/August 1992), pp. 39-47.

13. Thomas M. Jorde and David J. Teece, "Innovation and Cooperation: Implications for Competition and Antitrust," *Journal of Economic Perspectives*, vol. 4, no. 3 (Summer 1990), pp. 75-96; and Michael Katz and Janusz Ordover, "R&D Cooperation and Competition," *Brookings Papers on Economic Activity: Microeconomics* (1990), pp. 137-203.

equipment producers may have a clearer understanding about manufacturing technologies in which they should invest.[14]

Critics claim that collaboration can reduce the sense of rivalry that spurs firms to compete for technological leadership. Companies that are the first to innovate in high-technology markets gain an advantage over their competitors by introducing superior products or by lowering their manufacturing costs. In order to maintain market leadership, a firm's management must continue to invest in R&D and plan with an eye for the long term. With collaboration, R&D projects are pulled out of this strategic context and may undermine the advantage of certain companies by sharing information among competitors.[15]

Collaborative projects can, however, be organized in such a way as to retain some rivalry. For example, about 48 percent of SEMATECH's 1991 budget funded external R&D contracts with suppliers of semiconductor materials or equipment builders in order to improve their machinery or develop new production processes.[16] Because equipment suppliers compete for contracts, SEMATECH may have preserved a sense of technological competition among suppliers. The U.S. Advanced Battery Consortium, funded primarily by the Department of Energy and major U.S. auto manufacturers, is designed in a similar manner.[17] The techniques may not work in all situations, however, and decisions about whether the federal government should support R&D consortia should be assessed on a case-by-case basis.

Appropriate Federal Role for Technology Policy

To realize the benefits associated with TRP and similar programs, the federal government must choose research projects, a task normally handled by private businesses whose money is on the line. But some analysts contend that the

14. CBO, *Using R&D Consortia for Commercial Innovation.*

15. Joseph Morone and Damian Saccocio, "A Success-Based Competitiveness Policy," *Issues in Science and Technology* (Winter 1992-1993), pp. 61-72.

16. General Accounting Office, *Federal Research: Lessons Learned from SEMATECH*, GAO/RCED-92-283 (September 1992), p. 5. SEMATECH has also procured manufacturing equipment (such as optical lithography wafer steppers) for site testing by consortium members. See CBO, *Using R&D Consortia for Commercial Innovation*, p. 26.

17. Congressional Research Service, *Is DoD the Place to Fund Dual-Use Technology?* (May 17, 1993), pp. 69-76.

selections can be made in a manner consistent with an appropriate role of the federal government in a free-market economy.

When discussing the appropriateness of the government's role, these analysts draw a distinction between technology and industrial policy. It may be difficult to insulate federal support for certain industries from political decisionmaking, and federal agencies may be ill-equipped to judge the quality of a company's management or its business plans. Advocates of technology policy, however, see a role for the federal government in supporting basic research and selectively promoting generic applied research--the development of technologies that are useful among industries.[18]

The Defense Technology Conversion Council may have attempted to put this distinction into practice through its choice of the 11 areas that will receive priority for development in TRP projects. These fields are broad, dual-use in nature, and generally cover what have been identified as national critical technologies (see Appendix B). Other technology fields will be considered for TRP awards, but proposals must demonstrate convincingly that the research will have a pervasive effect on U.S. competitiveness.

RISKS OF FEDERAL SUBSIDIES FOR R&D

In the past, most federal research and development has been mission-oriented; that is, it has supported the goal of, say, building military aircraft or mapping genes. But TRP and other programs proposed by the Clinton Administration have much broader aims, namely, to encourage organizations to develop their research into commercial products and improve the productivity of U.S. companies. For this reason, they signal a distinct policy shift from previous administrations. It is a shift that promises rewards but also entails risks.

Limitations of Collaborative R&D

By improving communication and reducing duplication of effort, joint projects may in the short run improve the efficiency of R&D. Over time, however, collaboration can limit the diversity of research approaches or hamper the competition that drives technological progress, and perhaps slow the

18. See Lewis Branscomb, "Does America Need a Technology Policy?" *Harvard Business Review*, vol. 70 (March-April 1992), pp. 24-31.

resolution of a technical problem.[19] As in the case of SEMATECH, the structure of a cooperative effort can sometimes encourage rivalry among innovators. But collaboration is not a panacea--even carefully designed joint projects cannot ensure that participants will succeed in bringing a technology to the market or in making it commercially practical.

GCA Corporation, a contractor for SEMATECH that built manufacturing equipment for semiconductor producers, is a recent example of the limits of collaboration. When SEMATECH was formed in 1987, DoD officials supported its federal funding in order to prevent deterioration of the U.S. semiconductor industry in the face of Japanese competition. Defense planners feared that the United States could ultimately become dependent on foreign suppliers for chips used in military equipment.[20] Later, the focus of SEMATECH shifted toward improving the capabilities of suppliers of semiconductor manufacturing equipment. As one of the few U.S. builders of optical lithography equipment, GCA received somewhere between $30 million and $90 million in SEMATECH funding over the past four years, which it used to improve the technical sophistication of its machinery. But GCA's parent company, General Signal, decided recently to sell the company because prospects for equipment sales had declined. The company closed in May 1993, but General Signal has suspended liquidation while Clinton Administration officials ask U.S. firms to consider buying GCA. In this case, SEMATECH funds may have produced a technological success, but they may not yield their intended return because business fell off.

The results of collaboration could also conflict with other federal policy goals. For example, since many U.S. companies have multinational ties, it may be difficult to keep innovations created by federally funded consortia out of the hands of foreign competitors.[21]

Critics also contend that, despite some successful collaborative efforts, many joint R&D projects that were conducted during the 1980s have been disappointing. They note, for example, that projects around which many consortia have been formed are not those with the highest payoff, but rather

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19. F. M. Scherer, "Research and Development Resource Allocation Under Rivalry," *Quarterly Journal of Economics*, vol. 81, no. 3 (August 1967), pp. 359-394.

20. For more about the creation of SEMATECH, see CBO, *The Benefits and Risks of Federal Funding for Sematech*.

21. Richard R. Nelson and Gavin Wright, "The Rise and Fall of American Technological Leadership," *Journal of Economic Literature*, vol. 30, no. 4 (December 1992), pp. 1931-1964.

those that are of low priority.[22] One reason is that participants who are competitors may not trust the consortia with proprietary information or projects that are central to their corporate interests. Consortium members may also lack clear research objectives or may already have funded higher-priority programs with their own money.

Finally, the results of joint ventures in research can vary substantially depending upon the number of members and the degree of rivalry between them, the technical nature of innovations, how closely intellectual property rights are protected, and the proposed structure and tasks of the consortium. It will therefore be difficult to know in advance which of TRP's collaborative projects are likely to succeed.

Selecting Projects Is Difficult

Some critics argue that the federal government is less effective than private industry at choosing technology projects that are at the heart of TRP. ARPA, for example, is an agency with a strong reputation for technical competence, but it has spent money on disappointing projects. The uncertainties of R&D make some poor choices inevitable, and going down a fruitless path can be valuable if it prevents others from making the same mistake. Nevertheless, it has been argued that most governments--even that of Japan--have a poor record of selecting projects.[23]

Because private companies are motivated to select technologies with strong prospects for commercial success, some analysts would prefer that the federal government provide research and engineering tax credits to firms rather than fund specific R&D projects. But others believe that if left alone, firms in the private sector may not select certain socially beneficial R&D projects because they appear too risky.[24] According to this line of argument, the government may be in a better position to invest in a diversified portfolio of R&D projects than the private sector. And because tax credits are a broader mechanism for subsidizing innovation, it may be more difficult to verify that federal funds are not supporting specious R&D projects.

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22. Jerry Werner and Jack Bremer, "Hard Lessons in Cooperative Research," *Issues in Science and Technology*, vol. 7, no. 3 (Spring 1991), pp. 44-49.

23. Weidenbaum, "Sponsoring Research and Development," pp. 39-47.

24. See, for example, Gerard Wedig, "How Risky is R and D? A Financial Approach," *Review of Economics and Statistics*, vol. 72, no. 2 (May 1990), pp. 296-303. There is no consensus about whether firms are more reluctant than social planners to engage in risky R&D.

Politicization Is a Risk

Commentators also often raise the issue that federal support for R&D will become politicized--that project selection and funding decisions will be motivated by other than technical and commercial merit. Established industries with financial difficulties have a strong incentive to lobby the Congress and agencies for federal help. Federal agencies may advocate certain projects in order to heighten their role and importance, and Members of Congress may have incentives to provide help.[25] Funding for certain projects could also become entrenched politically and difficult to discontinue once they are no longer economically justifiable.[26]

Politicization also raises issues of fairness. Why should the government use taxes paid by healthy companies to assist firms that, perhaps because of poor management, are less successful than others or simply know how to use the political system to their advantage?[27]

Because it sets funding levels, some critics are particularly concerned that the Congress will manage federal R&D programs too closely. The Congress sometimes specifies how it would like to spend R&D dollars, a practice that supplants the judgment of technical experts or a peer review process. In some cases, the Congress specifies funding levels because it disagrees with the policies of the executive branch, or believes that certain technologies are promising and merit federal support. But projects may also be chosen in order to help particular companies, regardless of the efficacy of a program.

The Congress has already specified the nature of some TRP programs. Slightly more than $123 million, or 24 percent of total 1993 funding for TRP, was earmarked for specific projects in the fiscal year 1993 defense appropriations conference report. In most cases, the conference report referred to specific technologies, such as optics research, rather than names of companies. But in certain technical fields where few organizations conduct R&D, specifying a technology may be no different than targeting a firm.

Nor is the Congress alone in this practice; executive branch agencies may also be politically motivated when they propose projects for funding without

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25. Weidenbaum, *Small Wars, Big Defense.*

26. Linda Cohen and Roger Noll discuss this issue as related to large-scale R&D projects in *The Technology Pork Barrel* (Washington, D.C.: The Brookings Institution, 1991).

27. C. R. Neu and Michael Kennedy, *Do We Need Special Federal Programs to Aid Defense Conversion?* (Santa Monica, Calif.: RAND, February 1993).

employing a competitive review process.[28] Funds may be directed toward particular firms or organizations even if the money is designated only for a technology.

The authorizing legislation for TRP may provide some protection against overly detailed management. After consulting with Clinton Administration officials, the Defense Technology Conversion Council has decided not to carry out specific TRP funding requests made by the Congress for fiscal year 1993. Although the conference report reflects the intent of the Congress, the council believes that special project awards would contradict the authorization act, which directs that all TRP awards be made competitively. Organizations that were targeted in the conference report are encouraged to submit an application and compete, but will not necessarily receive a TRP award. One should note, however, that executive branch agencies may still choose to fund projects that were listed in the conference report in programs other than TRP.

Evaluating R&D Projects Is Difficult

Since it is hard to select the "right" projects for subsidies, it is all the more important to evaluate those projects to be sure that they are effective. Still, it is very difficult to evaluate projects in a careful manner.

Frequently, analysts describe R&D projects in terms of level of effort rather than measures of effectiveness. It may take years to collect data about such project outcomes as the number of associated patents, the value of sales, or reductions in cost resulting from a product or process. When outcome measures are available, they may obtain information about factors other than the federal investment. As a result, it is difficult to evaluate the importance of federal assistance in technology development, particularly when a company might have pursued the R&D on its own.

Some federal R&D programs are making a concerted effort at project evaluation. For example, managers of the Advanced Technology Program (ATP) at the National Institute of Standards and Technology compile data on their awards process as well as characteristics about applicants, technologies, and projects to gauge their own performance. They also require award recipients to provide data about project outcomes so that they can assess the ATP's effectiveness by using output measures. Because the ATP is new, only one interim evaluation--that of the first 11 awards--has been conducted so far.

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28. James Savage discusses various definitions of "unacceptable" federal funding practices in "Where's the Pork?" *Issues in Science and Technology* (Spring 1993), pp. 21-24.

The most important effects noted by participants were that they engaged in "riskier than usual" R&D projects, that the ATP prompted them to collaborate more closely with other organizations, and that their credibility within the financial community rose as a result of the award.[29]

Unfortunately, few measures of cost savings or product revenues that resulted from ATP projects are available. Nonetheless, the program's emphasis on project evaluation is admirable and should be an example for other federal R&D programs such as TRP.

EFFECTS ON DEFENSE EMPLOYMENT

In addition to posing some risks, TRP and other technology initiatives--although billed as defense conversion programs--are unlikely to reduce significantly the layoffs that will take place over the next few years because of cutbacks in defense spending. The defense budget cutbacks proposed by the Clinton Administration, coupled with those proposed under the Bush regime, would leave defense outlays at about $228 billion by 1998, measured in terms of 1993 dollars. This funding level represents a real reduction of 35 percent compared with the 1992 level. CBO estimates that under this scenario about 1.4 million defense-related jobs could be eliminated between 1992 and 1998, as compared with a total employed labor force in 1992 of 119 million.[30] These estimates include workers employed by defense contractors and their subcontractors and suppliers, as well as military personnel on active duty and civilians employed by the Defense Department. Private-sector jobs make up more than half of the total.

The projected number of jobs is not an estimate of unemployment caused by declines in defense spending, however, because some workers may retire, switch to commercial production lines within the same company, or find new jobs in growing areas of the civilian economy. Nonetheless, the magnitude of potential job displacement is noteworthy.

How many new jobs might be created by defense conversion initiatives? All of the Clinton Administration's defense conversion initiatives--which include assistance to workers and communities as well as technology programs--would add about $5.2 billion to federal budget authority in 1997,

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29. Solomon Associates, *The Advanced Technology Program: An Assessment of Short-Term Impacts* (Washington, D.C.: Solomon Associates, February 1993).

30. Congressional Budget Office, "Effects of Alternative Defense Budgets on Employment," CBO Paper (April 1993).

the last year covered by the initiatives. If annual TRP funding continues at its fiscal year 1993 level, it would increase budget authority by only about $0.5 billion in 1997. After adjustment for inflation, the increases measured in 1993 dollars amount to $4.8 billion for all initiatives and $0.5 billion for TRP. But measured in 1993 dollars, defense budget authority in 1997 would be about $77 billion lower than its 1992 level. TRP and other conversion initiatives would counterbalance only a small fraction of job losses in the defense sector.

Because they are focused on research and development, the defense conversion initiatives may have more significant effects on employment among scientists and engineers, particularly those key employees who have defense expertise. Moreover, if the initiatives improve overall productivity in the economy, they could eventually have a greater effect on jobs than the near-term numbers would suggest. As the Defense Conversion Commission noted, however, it may be a decade or longer before R&D programs result in new products or processes for the commercial market.[31] Any such benefits may therefore be years away.

IMPLEMENTATION ISSUES FOR TRP

TRP and related programs are, of course, not intended primarily to prevent or offset layoffs. They are designed to garner the national security and economic benefits discussed at the beginning of this chapter. In order to realize these benefits, administrators will have to overcome some important obstacles when carrying out TRP.

Budget Growth Could Cause Management Problems

Critics fear that the agencies that will manage TRP and other conversion initiatives may not cope effectively with budget growth and broadened responsibilities. Most of the five member agencies of the Defense Technology Conversion Council have or will experience significant growth in funding; in some cases the growth will be substantial. For example, without adjustment for inflation, ARPA's budget has more than doubled during fiscal years 1988-1993; between fiscal years 1992 and 1993 alone its budget rose by more than 40 percent (see Table 6). For fiscal year 1994, the Clinton Administration has proposed $2.2 billion in budget authority for ARPA, slightly lower than for fiscal year 1993 but still much larger than for fiscal year 1992.

31. Defense Conversion Commission, *Adjusting to the Drawdown* (December 31, 1992), p. 71.

TABLE 6. FUNDING LEVELS OF SELECTED R&D AGENCIES AND PROGRAMS (By fiscal year, in millions of dollars)

Agencies/Programs	1988	1989	1990	1991	1992	1993	1994[a]
Advanced Research Projects Agency							
Funding level	870.4	1,294.1	1,216.6	1,455.5	1,597.3	2,250.5	2,182.2
Percentage change from previous year	n.a.	49	-6	20	10	41	-3
Advanced Technology Program							
Funding level	0	0	10.0	35.9	47.4	67.9	199.5
Percentage change from previous year	n.a.	n.a.	n.a.	259	32	43	194
Manufacturing Extension Partnerships[b]							
Funding level	5.0	7.5	8.8	13.2	16.4	18.2	30.2
Percentage change from previous year	n.a.	50	17	50	24	11	66

SOURCE: Congressional Budget Office based on data from the Department of Defense and the National Institute of Standards and Technology.

NOTE: n.a. = not applicable.

a. Proposed.

b. Includes funding for Manufacturing Extension Centers, Manufacturing Outreach Centers, and State Technology Extension Programs.

Nor is rapid growth limited to programs managed within the Defense Department. NIST, part of the Department of Commerce, will manage two programs that offer conversion opportunities. Both are expected to grow substantially in coming years. The Advanced Technology Program provides funds on a cost-share basis to individual firms or joint ventures for technology development projects. The Manufacturing Extension Partnerships (MEP) program deploys manufacturing technology to small and medium-size businesses through a network of extension centers (see Appendix C). The ATP only began funding projects in fiscal year 1990, but it is supported by the Congress and grew by about 43 percent between fiscal years 1992 and 1993 without adjustment for inflation. The Clinton Administration proposed a 194 percent nominal increase for the ATP budget in fiscal year 1994. Likewise, the budget of MEP grew by 11 percent nominally between fiscal years 1992 and 1993, and would grow by 66 percent under the Administration's proposed fiscal year 1994 budget.

Given this budget growth, can agencies manage TRP and other conversion initiatives effectively? There is cause for concern. In fiscal year 1992, the Defense Department's ARPA, for example, employed 185 people, 109 of which were scientists and engineers. According to a recent study by the Congressional Research Service, mandatory personnel reductions at the Defense Department may have left ARPA with too few technical staff at a time when its budget is growing and its responsibilities for collaborative research are expanding. Some employees claim the agency has thus been rendered less effective.[32]

ARPA has, however, managed large short-term budget swings before, and TRP managers at the agency believe that they will be able to handle the influx of proposals. ARPA has a strong reputation for managing high-risk projects well by giving its program managers substantial decisionmaking authority. It has also relied heavily on "agents"--representatives from the military services to which a project will eventually be transferred--to help manage continuing contracts. This approach is similar to what will be used by the Defense Technology Conversion Council in administering TRP.

About 19 full-time staff--including technical personnel from the military services, ARPA, the Office of the Secretary of Defense, the National Aeronautics and Space Administration, NIST, the National Science Foundation, the Department of Energy, and support contractors--will help manage the phases in TRP associated with program outreach, proposal

32. Michael E. Davey, *The Defense Advanced Research Projects Agency*, Congressional Research Service Report 93-27 SPR (January 15, 1993).

evaluation, and awards. TRP managers also plan to hire more than 20 administrative support personnel on contract temporarily in late July to help handle the proposals. No other permanent personnel will be assigned for the proposal evaluation process. Instead, member agencies of the Defense Technology Conversion Council will "donate" evaluators to conduct the technical reviews. Interagency cooperation will be critical to the success of this approach.

Managers in NIST also believe that their program's design will enable them to handle the increase in their ATP budget, plus the administrative duties associated with their involvement in the TRP. All ATP proposals are subject to a formal review based on technical merit and each project's commercial potential. They are then ranked and the number of ATP awards is determined by the amount of funds available. Since every proposal is evaluated, officials contend that an increase in program funding will not greatly increase their work but will simply allow them to support more projects. NIST uses an automated system for processing proposals, and ATP managers believe they can handle increases in the volume of proposals and awards. The ATP employed only about 20 people as of March 1993, however, and more personnel may be required to track projects and evaluate their progress.

NIST also manages the MEP program, which the Clinton Administration plans to expand substantially. Under these plans, NIST would establish more than 100 extension centers--both manufacturing technology centers and smaller outreach centers--nationwide by 1997. If the MEP program were to manage all $190 million in fiscal year 1993 as well as a proposed $25 million in fiscal year 1994 funding for TRP manufacturing extension programs, its responsibilities would rapidly increase. MEP program managers believe that they will be able to handle the load. All proposals for new centers are evaluated competitively by the National Research Council. As with the Advanced Technology Program, the MEP may simply finance more of the top-ranking proposals.

Competing Management Styles

The use of an interagency process to evaluate and select TRP proposals could make the selection process more difficult by combining several different agency approaches to federal support for R&D. For example, in the past ARPA has identified and then cultivated high-risk technologies of potential military importance. ARPA's technical managers are allowed considerable independence in selecting technologies and managing projects. By contrast,

the NIST personnel who manage the Advanced Technology Program do not establish a research agenda. Proposals from all technology fields are evaluated and then ranked according to their technical merit and the degree to which they present convincing plans for commercialization. Awards are primarily industry-led; the quality of proposals drives the program's technology focus. It is not clear whether these competing philosophies can be fused to create a good selection process.

These concerns will apply to the management process that is being designed for TRP. For TRP technology development awards, the Defense Technology Conversion Council identified 11 broad technology areas that will receive the highest priority for development, an approach that resembles the strategy of ARPA.[33] The areas are broad and generally encompass what have been identified as national critical technologies (see Appendix B). Proposals covering other technologies will be considered, but they must demonstrate convincingly that the project will have a pervasive effect on the U.S. economy. The council also adopted some of the management approaches used by NIST for the Advanced Technology Program: TRP proposals will be evaluated formally using such criteria as technical merit and the degree to which plans for future defense or civilian product development are convincing. It remains to be seen whether this mixed approach will combine the best features of both strategies or will result in muddled management.

Agency R&D Projects Sometimes Overlap

As the Defense Conversion Commission noted in its report, some TRP programs duplicate existing programs. For example, although the projects are not precisely alike, there is some degree of overlap between projects such as Dual-Use Critical Technology Partnerships to be funded by ARPA under the TRP and other partnership programs at ARPA, the Department of Energy, NIST, and other agencies. Technology development projects funded by TRP may also overlap with R&D studies that are initiated by defense contractors, who are later reimbursed in part through DoD's Independent Research and Development (IR&D) program.

Program managers argue that TRP awards will augment rather than duplicate existing projects that are technologically promising but underfunded.

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33. The 11 are information infrastructure, electronics design and manufacturing, mechanical design and manufacturing, materials/structures manufacturing, health care technology, training/instruction technology, environmental technology, aeronautical technology, vehicle technology, shipbuilding industrial infrastructure, and advanced battery technology.

Some analysts also contend that overlap is not necessarily bad, since several technical approaches to a problem may help researchers reach their objective more quickly. The Clinton Administration is trying to minimize overlap--or at least insure that it is used productively--by encouraging coordination among agencies that finance R&D. In the case of the Defense Manufacturing Extension Program, for example, several of its projects are likely to be managed by the MEP program at NIST in cooperation with the Defense Department's ARPA.

Maintaining Cost Sharing

With the exception of awards to small business under the SBIR program, each TRP program requires recipients to share project costs. This provision serves several purposes. First, cost sharing and sunset clauses help ensure that award recipients have a vested interest in their project's outcome and will not become dependent on DoD support. Second, because it is willing to invest its own resources, the private sector provides federal agencies with information about which technologies it believes will have significant commercial potential. Cost sharing, then, is a policy tool to help overcome some of the most difficult aspects of federal support for R&D, namely, avoiding politicization and selecting projects.

Cost sharing is, however, effective only if the recipients of awards really contribute their share. In the case of TRP, there is some difference of opinion about what is an acceptable private contribution. Proposers are permitted to use other (nondefense) federal funds as part of their share in four of the eight TRP programs.[34] All eight programs consider contributions by state and local government agencies to be private funds. And in some cases, companies may claim IR&D project costs as part of their private contribution even though a portion of those expenses is later reimbursed by the Defense Department. The IR&D program allows defense firms to charge a portion of expenses associated with R&D projects that are initiated by private companies as overhead on DoD production contracts. The issue of whether IR&D costs should be considered private funding is highly controversial. Because firms initiate the projects themselves and have not been reimbursed in the past for all of their costs, industry trade associations

34. DoD, Office of the Secretary, "Defense Technology Conversion, Reinvestment and Transition Assistance Joint Program Solicitation No. SOL93-29" (May 14, 1993), p. 3.

contend that the IR&D program is not a subsidy.[35] The use of IR&D and similar types of contributions, however, may keep TRP's cost-share provision from having its intended effect.

Managers of TRP argue that one of the factors they will consider when evaluating proposals is the nature of private-sector funding. The proposer's own cash would be the most desirable form of private contribution, and funds from other federal agencies would make the proposal less attractive. If the Defense Technology Conversion Council receives many proposals and competition for TRP awards is stiff, it is likely that few federal funds will be counted as private contributions. Nonetheless, the issue deserves attention from those who will assess TRP's effectiveness.

TRP AND ALTERNATIVE POLICIES

In view of the issues connected with carrying out TRP and the risks associated with federal support of R&D programs, the Congress may wish to consider TRP within the context of other policy options that have similar goals.

For example, reform of defense procurement practices--eliminating unnecessary military specifications, complex accounting systems, and the like--is another means of promoting dual-use production and reducing the costs of acquisition. At least one defense industry executive believes that the most effective conversion policy the government could adopt would be to "create markets."[36] According to this line of reasoning, the federal government would induce defense companies to enter commercial markets by procuring civilian infrastructure and high-technology products. For both of these policy options, the means by which the government would encourage private R&D investment is simply to signal industry what it would like to procure.[37]

Another option would use R&D tax credits rather than matching grants for dual-use technologies. Tax incentives are attractive to some analysts because the private sector maintains responsibility for initiating projects and

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35. See, for example, Aerospace Industries Association, *Maintaining Technological Leadership: The Critical Role of IR&D/B&P* (Washington, D.C.: Aerospace Industries Association, 1989). Appendix C describes the IR&D program in more detail.

36. Statement of Renso Caporali, Chairman, Grumman Corporation, before the Subcommittee on Defense, Senate Committee on Appropriations, May 27, 1993.

37. For empirical evidence that government procurement can motivate private R&D investment, see Frank Lichtenberg, "The Private R&D Investment Response to Federal Design and Technical Competitions," *American Economic Review*, vol. 78, no. 3 (June 1988), pp. 550-559.

bears the financial risks of R&D.[38] Because many companies would qualify, tax credits could help to affect the investment decisions of defense firms relatively quickly. But such a broad-based policy may also make it difficult to monitor the validity and effectiveness of reported R&D expenditures.

Policy options such as these and direct funding programs like TRP are not mutually exclusive. The Congress should consider, however, whether plans made for TRP are likely to address its goals more effectively than other policy options.

38. Weidenbaum, *Small Wars, Big Defense*, p. 204.

APPENDIXES

APPENDIX A

FURTHER DESCRIPTION OF TRP PROGRAMS

This appendix provides a more detailed description of each TRP program and poses a hypothetical example of how it might work.

TECHNOLOGY DEVELOPMENT PROGRAMS

Technology development programs include Dual-Use Critical Technology Partnerships, Commercial-Military Integration Partnerships, and Defense Advanced Manufacturing Technology Partnerships. Regional Technology Alliance awards may be used for technology development projects or for some technology deployment projects, but are discussed along with the first three.

Technology development projects should cover a 12- to 24-month period of performance, and proposers are expected to submit options for additional 12- to 24-month periods. These options may be funded with future TRP appropriations or with funds from an agency outside the TRP program. Proposals will be evaluated on the basis of their scientific and technical merit, their management plan, the potential benefits the project could bring to the industrial base, and the likelihood that the technology will be brought to market and made commercially viable.

Dual-Use Critical Technology Partnerships

This partnership program, which is administered by the Advanced Research Projects Agency (ARPA), provides federal funds to promote the development and application of critical technologies--the term used to describe fields considered most important for U.S. national security and economic growth (see Appendix B). The fiscal year 1993 legislation authorizing Critical Technology Partnerships lists 14 technologies that projects may undertake, including fields in electronics, materials, information and communications, and manufacturing processes and controls. The Defense Technology Conversion Council, however, is neither bound to make awards in each of these technologies nor restricted to only these fields.

Proposals must be submitted by two or more firms or a not-for-profit research corporation established by two or more firms. Federal laboratories, agencies of state governments, colleges and universities, and other entities

may also participate. Consortia must provide at least 50 percent of costs from nonfederal sources each year, but the federal share can be raised for certain projects at the discretion of the Secretary of Defense. This program has no sunset provision--no time limit after which federal funding must cease.

The partnership program was established in fiscal year 1991 with a $50 million appropriation (see Table A-1). The Congress appropriated $60 million for the partnerships in fiscal year 1992, but the Office of the Secretary of Defense did not release funds until early 1993. ARPA is forming partnerships with its fiscal year 1992 funds in technologies such as data storage for magnetic and optical recording, precision investment casting simulation technology, and all optical network components and communications architecture. Another $81.9 million is available for fiscal year 1993 projects.

Chapter II provided an example of an actual Dual-Use Critical Technology Partnership award. The following is a hypothetical example:

> Machine Tools America (MTA), a consortium of machine-tool builders and producers of numerical control devices, submits a proposal for work on flexible robotic systems. MTA plans to develop software that will allow users of robotic equipment in the fighter aircraft industry to transfer data between several different numerical control operating systems. TRP agrees to match a $4.5 million private cash contribution from the consortium, which will support work over two years. The consortium also receives related technical assistance from the National Institute of Standards and Technology by separate arrangement.

Commercial-Military Integration Partnerships

Commercial-Military Integration Partnerships will provide federal funds to support civilian technologies that can enhance the capabilities of military equipment--so-called spin-ons. These partnerships could help address concerns about reconstituting the defense industrial base in the event of a protracted war by fostering the use of commercially available components in military equipment.

TABLE A-1. DUAL-USE CRITICAL TECHNOLOGY PARTNERSHIP AWARDS FOR FISCAL YEAR 1991

Scientific Field	Consortia	Funding (In millions of dollars)
Ceramic Fiber Consortium for Gas Turbine Engine Components	Seven engine manufacturers with the partial sponsorship of ARPA, Air Force Wright Laboratory, and NASA Lewis Research Center	3
Optoelectronics with Broad Applications for High-Performance Computing and All Optical Networks	Optoelectronics Technology Consortium: Honeywell, General Electric, AT&T, and IBM. Optical Network Technology Consortium: Bellcore, Northern Telecomm, Columbia University, and Hughes Aircraft	17
Superconducting Electronics	Superconducting Electronics Consortium: MIT, Lincoln Laboratory, AT&T, and IBM	2
Develop Key Databases for Effective Test of Speech Processing Systems	Linguistic Data Consortium composed of industry, universities, and government agencies and led by the University of Pennsylvania	5
Scalable Computing Systems, in Support of the High-Performance Computing Initiative	Scalable Computing Systems Consortium with MIT as the executive agent	9
Advanced Static Random Access Memory to Reduce Areas Required for Memory Circuits	Micron Technology	9
Advanced Composites Manufacturing Technologies	Advanced Composites Technology Consortium: DuPont, Hercules, Lanxide, the University of Delaware, and ICI America	5
Total		50

SOURCE: Advanced Research Projects Agency.

Commercial-Military Integration Partnership awards can be made to a single firm or to a not-for-profit research organization established by two or more firms. Federal laboratories, state agencies, and colleges and universities may also participate. Stricter cost-sharing rules apply to these partnerships than to other programs: DoD will provide no more than 50 percent of project funding in the first year, 40 percent in the second, and 30 percent in subsequent years. Support cannot be provided for more than five years. A partnership may, however, use other federal support for its share of funds. Funding for this new program totals $42.1 million for fiscal year 1993.

Because it is new, there are no examples of actual awards under this program. A hypothetical example of a Commercial-Military Integration Partnership follows:

> The XYZ Semiconductor Manufacturing Corporation, a leader in research of micro-electromechanical systems (MEMS), agrees to work with two defense electronics companies and a military laboratory to apply its technology to inertial guidance units. MEMS technology would allow defense electronics companies to reduce costs greatly and improve the accuracy of air-dropped weapons. The research joint venture raises $5 million for the five-year project, which includes a $500,000 award that XYZ received from the National Aeronautics and Space Administration, the full-time effort of four scientists and engineers, and cash. Federal funds match the consortium's funding in its first year, but provide only 40 percent of project costs in the second year and 30 percent in its third through fifth years.

Defense Advanced Manufacturing Technology Partnerships

This program will provide federal assistance to develop dual-use manufacturing technologies by means of collaboration among two or more private-sector firms. Federal laboratories, state agencies, and institutions of higher learning may also participate if approved by the Secretary of Defense. Particular attention will be paid to technologies that reduce health, safety, and environmental hazards associated with existing manufacturing processes. These partnerships were first authorized in the fiscal year 1992 defense budget, but the Congress did not appropriate funding for that year. Funding for fiscal year 1993 totals $23.5 million.

At least 50 percent of project costs must come from nonfederal sources, except at the discretion of the Secretary of Defense. Authorizing language for

Defense Advanced Manufacturing Technology Partnerships does not specify the upper time limits of federal support.

For example, imagine that Big Chip Producer, Inc. (BCP) and a semiconductor equipment manufacturer join forces for a Defense Advanced Manufacturing Technology Partnership. They propose to develop a manufacturing process that significantly reduces the volume of solvents and acids required to etch circuit patterns on silicon wafers during chip production. The equipment manufacturer provides $1.5 million in personnel compensation, research facilities, and machinery while BCP contributes $3 million, consisting of cash and compensation for three full-time researchers. The consortium's proposal is selected to receive a matching grant of $4.5 million from the federal government.

Regional Technology Alliances

The goal of the Regional Technology Alliance program is to provide federal funds that assist in developing applications of critical technologies. Regional Technology Alliance centers might, for example, operate equipment testbeds or offer prototype development and testing services to alliances of local companies. Funds are to be provided to alliances of organizations at existing regional concentrations of research and development activities.

Alliances must include at least one firm that does business in a locality and one state or local government agency, not-for-profit organization, or institution of higher learning operating in that same region. TRP funds will provide up to 50 percent of a center's funding each year for a maximum of six years. Other federal funding may be used as a recipient's share of project costs.

As an example of a Regional Technology Alliance, suppose that three aerospace companies operating in a state called Southwest form an alliance with the University of Southwest. They submit a TRP proposal to apply some of the university's developments in advanced computer-aided design and manufacturing software to their aircraft design projects. The TRP award would aid their efforts to establish a testbed for their software developments at the university, which would then provide this service to other local companies for a nominal fee. The three companies each contribute $250,000 annually in the form of full-time personnel, facilities, and cash for the consortium's cost share. Matching federal funds are made available for up to six years.

The Regional Technology Alliance program was authorized originally for fiscal year 1992 under the name "Critical Technology Application Centers," but the Congress did not appropriate funding for it at that time. For fiscal year 1993, available program funding totals $90.5 million.

TECHNOLOGY DEPLOYMENT PROGRAMS

Two TRP programs focus on disseminating technology: the Defense Manufacturing Extension Program and the Defense Dual-Use Assistance Extension Program. Proposals for projects within this category will be evaluated according to the size of the population to be served, the degree to which the needs of firms that have been defense suppliers are met, and the quality of plans for management and service delivery. They must also reflect an understanding of existing state and local extension services in their region so that the project will coordinate with, but not duplicate, those efforts. Projects may take the form of conventional manufacturing extension services (in which case they should target businesses with 500 or fewer employees), or less traditional programs such as developing an electronic network between a prime contractor and its suppliers.

Defense Manufacturing Extension Program

The Defense Manufacturing Extension Program will provide federal funds to enhance existing manufacturing extension programs and help them address the needs of businesses that have been defense suppliers. Programs, which must be run by state or local governments or not-for-profit organizations, can receive up to 50 percent of the funding required to operate a manufacturing extension center for a maximum of five years. Recipients are subject to a formal program review after their third year of operation.

In its report, the Defense Conversion Commission singled out the Defense Manufacturing Extension Program as an example of a conversion initiative that duplicates existing federal programs.[1] For example, the Defense Department's ManTech program, the Regional Technology Transfer Centers of the National Aeronautics and Space Administration, various laboratories of the Department of Energy, and the Manufacturing Extension Partnerships program of the National Institute of Standards and Technology are all federal programs that support manufacturing extension efforts. The Defense Conversion Commission recommended that these programs be better

1. Defense Conversion Commission, *Adjusting to the Drawdown* (December 31, 1992), p. 71.

integrated and administered by agencies with missions more closely related to industrial extension than the Defense Department.

According to TRP organizers, many projects funded by TRP's Defense Manufacturing Extension Program are likely to be administered by NIST in concert with its Manufacturing Extension Partnerships program. A hypothetical case based on an example in TRP's *Program Information Package* follows:[2]

> A nonprofit corporation submits a proposal to establish HLB Services, which will demonstrate computer hardware and software related to manufacturing, assess the equipment needs of individual firms, and set up a teaching factory, among other services. HLB will be located in Northeast State and will serve a population of 7,000 small manufacturers within one hour's driving time of its facility. About 30 percent of those companies have been suppliers to the Defense Department. HLB's operating budget would total $6 million a year after a one-year start-up level of $3 million. Northeast State provides a cash grant for the private cost share in its first year, and HLB plans to use a combination of state funds and revenues from its services in future years.

The Manufacturing Extension Program was first authorized in fiscal year 1992, but the Congress did not appropriate it funding. Available funds for fiscal year 1993 total $87.9 million, compared with $18.2 million for NIST's Manufacturing Extension Partnerships program in the Department of Commerce budget.[3]

Defense Dual-Use Assistance Extension Program

Among the eight TRP programs, the Defense Dual-Use Assistance Extension Program is one of the broadest in scope. Its goal is to support government agencies or other organizations that promote dual-use production. Funds from this program can be used to help firms adopt civilian management and marketing practices, identify dual-use technology markets into which the firms

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2. Advanced Research Projects Agency, *Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance* (March 10, 1993), p. A-13.

3. An additional $0.5 million in funding from NIST's State Technology Extension Program (STEP) is available for providers of manufacturing extension services under TRP, raising total funding to $87.9 million. STEP is one component of NIST's Manufacturing Extension Partnerships program. See DoD, Office of the Secretary, "Defense Technology Conversion, Reinvestment and Transition Assistance Joint Program Solicitation No. SOL93-29" (May 14, 1993), p. 4.

can diversify, promote exports, or locate potential suppliers and subcontractors.

Federal funds can be used to provide up to 50 percent of project funding in the first year, 40 percent in the second, and 30 percent in the third and subsequent years. Funding from agencies other than the Defense Department may be used as part of the proposer's cost share. The program's authorizing legislation does not include an upper time limit for TRP funds, but no new projects will be started after fiscal year 1995 and no funding for this program will be awarded after September 30, 1998. A total of $90.8 million is available for this program in fiscal year 1993. How might a Dual-Use Assistance Extension project work?

A group of large, private defense contractors might establish a not-for-profit center to improve manufacturing technologies among small businesses that supply them with key parts. The industrial consortium formed by the contractors would submit a TRP proposal to link small suppliers of dual-use parts--in this case, machined engine components for military and civilian motor vehicles--with their customers over an electronic network. The proposers believe that with an electronic network, suppliers can speed up orders and verify their accuracy more easily, improve the flow of communication about parts specifications between vendors and purchasers, and share information with one another about quality control and other issues. Members of the industrial consortium contribute a total of $400,000 in start-up costs to develop and publicize the electronic network. To help pay its first-year costs, the group receives federal funds equal to its contribution. More funding may be available once the program's first-year operations are evaluated.

MANUFACTURING EDUCATION AND TRAINING PROGRAMS

Two TRP programs aim to integrate military and civilian engineering education: the Manufacturing Engineering Education Grant Program, and Manufacturing Experts in the Classroom. The federal government will fund up to 50 percent of project costs. Although no period is specified after which federal support must cease, the council has devised expected term lengths which usually run from two to three years.

A wide variety of projects could be funded with these awards (see Table A-2). For example, a university might use the award to develop a curriculum that cuts across engineering disciplines and combines hands-on product development with academic training. Funds could be used to create

TABLE A-2. MANUFACTURING ENGINEERING EDUCATION PROGRAMS

Type of Program	Length and Size of Awards
Engineering Education in Manufacturing Across the Curriculum	Three-year awards up to a total of $3 million each
Practice-Oriented Master's Degree	Three-year awards up to a total of $300,000 each
Retraining the Manufacturing Work Force	Three-year awards up to a total of $1.5 million each
Educational Traineeships for Defense Industry Engineers	Three-year awards up to a total of $600,000 each
Manufacturing Engineering Education Coalitions	Two-year awards up to a total of $4 million each
Supplemental Education Awards to Ongoing Centers and Coalitions Devoted to Manufacturing	Three-year awards up to a total of $2.5 million each
Individual/Group Innovations in Manufacturing Engineering Education	Three-year awards totaling from $150,000 to $600,000 each
Manufacturing Experts in the Classroom	Three-year awards up to a total of $600,000 each

SOURCE: Congressional Budget Office based on information from the Advanced Research Projects Agency.

fellowships for displaced defense engineers so that they can return to school to learn commercial manufacturing practices and earn master's degrees. An award of funds from this category might also supplement the funds of National Science Foundation engineering research centers in order to tailor their work toward education in dual-use manufacturing technologies.

Manufacturing Engineering Education Grant Program

Authorizing legislation established the Manufacturing Engineering Education Program to provide funds to improve existing manufacturing engineering programs at colleges and universities or to establish new ones. Funds may be approved for any projects that fall within this framework. Funding of $25 million was appropriated in fiscal year 1992, but funds were not released for obligation until March 1993. The Clinton Administration plans to award $20.1 million in fiscal year 1992 funding by October 1, 1993, and $23.5 million in fiscal year 1993 funding over the 1993-1994 period.

Manufacturing Experts in the Classroom

The Manufacturing Experts in the Classroom program was authorized to make awards to colleges and universities that offer temporary positions to manufacturing experts to teach in their engineering programs. The goal of the program is to expose students to the more practical side of engineering. Projects must last at least two years.

For fiscal year 1992, $5 million in funds was appropriated, but was later rescinded. For fiscal year 1993, funds available for awards total $4.6 million.

APPENDIX B

COMPARISON OF CRITICAL TECHNOLOGIES

A comparison of technologies identified as having the highest priority for the Technology Reinvestment Project follows. Critical technology lists compiled by the Office of Science and Technology Policy, the Department of Commerce, and the Department of Defense are included.

TABLE B-1. CRITICAL TECHNOLOGIES LISTS

Technology Reinvestment Project	National Critical Technologies	Commerce Emerging Technologies	Defense Critical Technologies
Materials			
Materials/structures manufacturing	Materials synthesis and processing	Advanced materials	Composite materials
	Electronic and photonic materials	Advanced semiconductor devices	Semiconductor materials and microelectronic circuits
	Ceramics	Superconductors	Superconductors
	Composites	Advanced materials	Composite materials
	High-performance metals and alloys		
Manufacturing			
Mechanical design and manufacturing	Flexible computer integrated manufacturing	Flexible computer integrated manufacturing	
	Intelligent processing equipment	Artificial intelligence	Machine intelligence and robotics
Electronics design and manufacturing	Micro- and nano-fabrication		
	Systems management technologies		
Information and Communications			
Information infrastucture	Software	High-performance computing	Software producibility
Electronics design and manufacturing	Microelectronics and optoelectronics	Advanced semiconductor devices	Semiconductor materials and microelectronic circuits
		Optoelectronics	Photonics
	High-performance computing and networking	High-performance computing	Parallel computer architectures
	High-definition imaging and displays	Digital imaging	Data fusion
	Sensors and signal processing	Sensor technology	Signal processing
			Passive sensors
			Sensitive radars
			Machine intelligence and robotics
	Data storage and peripherals	High-density data storage	Photonics

TABLE B-1. CONTINUED

Technology Reinvestment Project	National Critical Technologies	Commerce Emerging Technologies	Defense Critical Technologies
Training/instruction technology	Computer simulation and modeling	High-performance computing	Simulation and modeling Computational fluid dynamics
Biotechnology and Life Sciences			
	Applied molecular biology	Biotechnology	Biotechnology materials and processes
Health care technology	Medical technology	Medical devices and diagnostics	
Aeronautics and Surface Transportation			
Aeronautical technologies	Aeronautics		Air-breathing propulsion
Vehicle technology	Surface transportation technologies		
Shipbuilding industrial infrastructure			
Advanced battery technology			
Energy and Environment			
	Energy technologies		
Environment technology	Pollution minimization, remediation, and waste management		
Other			
			High-energy density materials Hypervelocity projectiles Pulsed power Signature control Weapon system environment

SOURCE: Congressional Budget Office based on information from the Advanced Research Projects Agency and the Office of Science and Technology Policy.

APPENDIX C

SIMILAR FEDERAL R&D PROGRAMS

Proposals for Technology Reinvestment Project (TRP) awards will be reviewed and selected by the Defense Technology Conversion Council, composed of representatives from the Advanced Research Projects Agency (ARPA) of the Department of Defense (DoD), the National Institute of Standards and Technology (NIST), the Department of Energy's Defense Programs Office (DOE/DP), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). The council was organized so that ARPA could draw on the expertise of other agencies and coordinate TRP programs with continuing federal programs.

THE DEPARTMENT OF DEFENSE

Budget authority for the conduct of defense research and development (R&D) is expected to total $41.6 billion in fiscal year 1993 and will account for nearly 60 percent of federal R&D. The majority of these funds will be used to design and develop specific weapon systems and military equipment. DoD does, however, spend considerable amounts on science and technology--early phases of research and development that include basic research through more advanced technology development. DoD will fund some $8.4 billion in science and technology work in fiscal year 1993, excluding the Strategic Defense Initiative.

Because defense science and technology programs support early stages of R&D, many could be considered dual-use in nature. This paper, however, limits its background on projects similar to the TRP to three DoD agencies or programs: ARPA, the Manufacturing Technology (ManTech) program managed by the Office of the Assistant Secretary of Defense for Production and Logistics, and the Independent Research and Development program.

Advanced Research Projects Agency

Formerly known as the Defense Advanced Research Projects Agency, ARPA is a defense agency independent of the military services that develops high-risk technologies that have potential military importance. Because of its role in the development of such technologies as packet switching, phased array radar, advanced materials, and parallel processing for supercomputers, ARPA

has a reputation for successfully selecting and supporting important technologies.

Although it has a fiscal year 1993 budget of about $2.3 billion, ARPA is relatively small. Its professional staff numbers just over 100. Although defense budgets have declined in recent years, ARPA's budget has grown significantly; it more than doubled in nominal terms between fiscal years 1988 and 1993 (see Table 6 on page 37). The Bush Administration had proposed reducing ARPA's funding in fiscal year 1993 by about $300 million, but instead the Congress increased its appropriations by over $660 million, including nearly $500 million in TRP funding. The Clinton Administration has proposed a budget of $2.2 billion for fiscal year 1994.

In fiscal year 1991, ARPA was first appropriated $50 million for the Defense Critical Technology Partnerships program and funded seven projects. Another eight partnerships are being formed and will receive awards from the $60 million appropriated in fiscal year 1992; the funds were not available for obligation until March 1993. ARPA also supports research on dual-use technologies such as flat-panel display manufacturing methods, advanced materials, and other manufacturing technologies.

In 1989, ARPA was given authority to enter into "agreements and other transactions."[1] Agreements allow ARPA more flexibility in its financial dealings. Firms consider them preferable to contracts because they allow contractors to retain intellectual property rights over the results of the projects. Under agreements, firms are also permitted to use accounting and auditing standards more like those in private industry. However, agreements have not been used widely, in part because ARPA was required to obtain the approval of the Director of Defense Research and Engineering (DDR&E) and the Undersecretary of Defense for Acquisition before signing such agreements. During the Bush Administration, DoD was somewhat reluctant to approve such arrangements, particularly after ARPA signed its first agreement with Gazelle Microcircuits in 1990. ARPA's director at the time, Craig Fields, was reportedly reassigned to the DDR&E office after he signed a $4 million agreement to invest in Gazelle without obtaining higher approval within DoD. Critics claim Dr. Fields was reassigned because the agreement too closely resembled picking winners.[2]

1. 103 Stat. 1403, 10 U.S.C. 2371.

2. See the comments of Senator Jeff Bingaman in Cynthia Beltz, *Caught in the Crossroads: Do We Need a Civilian DARPA in the Defense Department?* (Washington, D.C.: American Enterprise Institute, July 28, 1992).

The Manufacturing Technology Program

ManTech sponsors the development of new manufacturing processes for use by defense contractors. ManTech funds are not used to purchase manufacturing equipment. (In the past, the Industrial Modernization Incentives Program and facilities modernization funds have played this role.) Instead, the ManTech program develops manufacturing technologies and helps disperse the resulting innovations among defense producers. It focuses particularly on the production of military equipment, but many of its innovations are applicable to civilian manufacturing as well. One of ManTech's more famous projects was the development of numerically controlled machine tools. It typically finances 200 projects each year.

The ManTech program is carried out by each military service and some defense agencies, but is coordinated by the Office of the Assistant Secretary of Defense for Production and Logistics. Beginning in fiscal year 1994, this responsibility will be transferred to the Office of the Director of Defense Research and Engineering. This shift reflects a new emphasis within DoD on concurrent engineering--a philosophy that stresses the importance of planning for the manufacture of a product from the early stages of design. In the past, the Congress has appropriated about $150 million to $200 million a year for ManTech, with levels as high as $300 million. The Clinton Administration has proposed $148 million for fiscal year 1994 (see Table C-1).

Independent Research and Development/Bid and Proposal Program

Under the Independent Research and Development/Bid and Proposal (IR&D/B&P) program, defense contractors initiate research and development projects of their choosing. The companies are later reimbursed for a portion of their efforts by means of indirect (overhead) charges on DoD contracts. Although most firms intend to apply the results of IR&D projects to specific weapon systems, projects sometimes have applications in the civilian sector as well. Industry trade associations claim that IR&D projects have led to developments in composite materials, advanced radars, advanced integrated circuits, signal processing technology, optics, sensors, and lasers.[3] Other analysts, however, point out that the Defense Department has been reimbursing a larger share of contractor bid and proposal expenses than inde-

3. Aerospace Industries Association, *Maintaining Technological Leadership: The Critical Role of IR&D* (Washington, D.C.: Aerospace Industries Association, 1989).

TABLE C-1. MANTECH FUNDING LEVELS
(By fiscal year, in millions of dollars)

Agency	1989	1990	1991	1992	1993	1994[a]
Army	20	25	32	28	34	b
Navy	43	51	110	74	105	b
Air Force	96	85	109	61	103	b
Defense Logistics Agency	11	15	11	17	55[c]	b
Office of the Secretary of Defense	0	0	50	100	c	148
Total	170	176	312	280	297	148

SOURCES: Department of Defense and the Congressional Research Service.

a. Proposed.
b. Beginning in fiscal year 1994, ManTech appropriations are centered in the Office of the Secretary of Defense rather than in individual military service and agency accounts.
c. Total appropriations for defense agencies excluding the Advanced Research Projects Agency.

pendent research and development--perhaps encouraging more marketing than innovation.[4]

Reimbursements for IR&D projects charged to DoD contracts totaled $3.4 billion in fiscal year 1992 (see Table C-2). In comparison, ARPA's fiscal year 1992 budget was less than half as large--$1.6 billion. In fiscal year 1992, the Congress directed DoD to increase the share of company-initiated research and development costs that it reimburses through the IR&D program and broaden the scope of projects that are eligible. Because of the overall downturn in military procurement spending, however, DoD reimbursements have remained steady or declined; defense contractors are initiating less independent research and development since the prospects for future defense sales have deteriorated.

4. C. D. Vollmer, "The Future Defense Industrial Environment," *Washington Quarterly* (Spring 1990), pp. 93-109.

TABLE C-2. INDEPENDENT RESEARCH AND DEVELOPMENT/BID AND PROPOSAL COSTS INCURRED BY MAJOR DEFENSE CONTRACTORS (By fiscal year, in millions of dollars)

	1988	1989	1990	1991	1992
Costs Incurred by Industry	7,222	7,101	7,269	7,192	7,001
Allowable Costs[a]	5,658	5,638	5,762	6,156	6,166
DoD Share of Allowable Costs[b]	3,492	3,453	3,431	3,377	3,389

SOURCES: Defense Contract Audit Agency and the Office of the Secretary of Defense.

a. Maximum value that can be recouped through overhead charges on DoD contracts. Company divisions that recover relatively large amounts of IR&D/B&P costs negotiate this ceiling annually with DoD through advance agreements.

b. Excludes reimbursements recouped on DoD Foreign Military Sales contracts.

THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

As part of the 1988 Omnibus Trade and Competitiveness Act, the National Bureau of Standards (NBS), a research facility of the Department of Commerce, was renamed the National Institute of Standards and Technology. NBS had a long history of working effectively with industry in metrology--the science of measurement--and in setting technology standards. As NIST, however, its role has been expanded to include the promotion of civilian R&D. In addition to its intramural research into metrology and standards, NIST received funding for extramural programs designed to speed the commercialization of R&D and to disseminate manufacturing technology. These programs include the Advanced Technology Program and Manufacturing Extension Partnerships.

The Advanced Technology Program (ATP)

First authorized in the Omnibus Trade and Competitiveness Act, ATP provides seed money on the basis of cost sharing to individual firms or joint ventures among organizations in order to accelerate the development of precompetitive generic technologies. Universities, not-for-profit organizations, and federal laboratories may also participate in projects funded by ATP. Although ATP was established in 1988, the Congress did not appropriate

funding for it until fiscal year 1990. Awards are selected in periodic competitions from proposals that have been evaluated and ranked by panels of technical and business experts. Three competitions have been held to date.

One example of an ATP project is a five-year, $1.3 million award made in fiscal year 1991 to the Advanced Display Manufacturers of America Research Consortium. This nine-member joint venture is developing manufacturing and testing technology to produce flat-panel displays. The consortium is providing $7.6 million for the project.

ATP award recipients are expected to provide at least 50 percent of project costs. Federal awards of up to $2 million for single firms offset direct project costs over a period of up to three years. There is no dollar limit on the size of awards to joint ventures, and federal support can offset up to 50 percent of direct and indirect expenses for up to five years. Participants are allowed to patent or copyright the results of an ATP project, but the federal government often retains a nonexclusive license for the use of the technology.

Unlike ARPA, NIST is not assigned a specific mission to any particular industry. Consequently, the ATP does not target specific technologies when it makes its awards; research objectives are set by the pool of applications received in each competition. However, projects must pertain to precompetitive generic technologies. Written evaluations of each proposal are conducted by technical and business experts--NIST employees and other experts from business, academia, research organizations, or other federal agencies such as ARPA, NASA, DOE, and the National Institutes of Health. Much of the ATP evaluation process has been used as a model for TRP.

As of December 1992, the ATP had funded 60 projects, including 18 joint ventures covering areas such as biotechnology, microelectronics, advanced materials, and advanced data storage systems. About $187 million in federal money has been committed to these programs, with about $210 million provided additionally by award recipients. More than half of the awards to single firms have gone to small businesses.

Funding for the ATP has grown from $10 million in fiscal year 1990 to nearly $68 million in fiscal year 1993. The Clinton Administration proposed $199.5 million in funding for fiscal year 1994 and increases rising to $680 million by fiscal year 1997.

Manufacturing Extension Partnership (MEP) Program

The MEP program's goal is to enhance the productivity of small and medium-sized businesses by transferring information about manufacturing technology and helping firms solve their fabrication problems. Examples of services provided by this extension program include assistance in selecting and using software, training courses, and factory assessments. The extension centers charge a nominal fee for their services. When asked whether private consultants do not already provide the same sort of services to industry, MEP officials respond that many consultants are beyond the means of small businesses.

Three types of centers make up the MEP program: Manufacturing Technology Centers (MTCs), also known as Hollings Centers, designed to serve regions with relatively dense industrial concentration; Manufacturing Outreach Centers (MOCs), which serve as satellites or smaller versions of MTCs for areas with lower concentrations of manufacturing; and State Technology Extension Programs (STEPs), state industrial extension programs usually run by community colleges that receive grant awards and technical assistance from NIST. Program managers hope eventually to link a combination of MTCs, MOCs, and STEPs with an electronic network so that they can share information about manufacturing practices.

Individual MTCs must be sponsored by a not-for-profit institution or organization, which may include state agencies. NIST provides 50 percent of center costs--up to $1.5 million to a center in the year in which it is initiated and up to $3 million in its second and third years, with funds tapering off thereafter. Federal funding takes the form of renewable cooperative agreements, which are contingent upon annual reviews and a more formal third-year review. Currently, MTCs cannot receive more than six years of federal support, although there is interest both in the Congress and within MEP management in dropping this sunset provision. In order to shield NIST from political pressure, proposals for new centers are evaluated by the National Research Council.

Seven MTCs have been established to date: in Cleveland, Ohio; Albany, N.Y.; Columbia, S.C.; Ann Arbor, Mich.; Kansas City, Kans.; Minneapolis, Minn.; and Los Angeles, Calif. The Clinton Administration supports establishing more than 100 manufacturing extension centers (MTCs and MOCs) nationwide by 1997 and hopes to expand STEPs into 38 states.

TABLE C-3. FUNDING FOR THE MANUFACTURING EXTENSION PARTNERSHIP PROGRAM
(By fiscal year, in millions of dollars)

Programs	1988	1989	1990	1991	1992	1993	1994
Manufacturing Technology Centers (Including Manufacturing Outreach Centers)	5.0	7.5	7.5	11.9	15.1	16.9	a
State Technology Extension Programs	0	0	1.3	1.3	1.3	1.3	a
Total	5.0	7.5	8.8	13.2	16.4	18.2	30.2[a]

SOURCE: National Institute of Standards and Technology.

a. As of fiscal year 1994, the Manufacturing Technology Center program and the State Technology Extension Programs have been combined under the Manufacturing Extension Partnership program. Separate funding levels were not available.

For fiscal year 1993, combined federal funding for the MEP program totals $18.2 million (see Table C-3). By comparison, the Agricultural Extension Service had a budget of about $1 billion in 1992, and the federal share was more than $400 million.

NIST does encourage evaluation plans by each MTC, but they are not conducted uniformly among centers. Centers in Ohio and New York have surveyed their client firms and reported associated increases in productivity, sales, and jobs, but clients were not surveyed randomly. A 1991 General Accounting Office study, however, did report $139 million in cost savings among MTC clients during the first 30 months of the program. GAO estimates that this was an eight-to-one return on investment.

DEPARTMENT OF ENERGY

The Department of Energy is responsible for long-term R&D of nuclear weapons, energy technologies, and energy conservation. The Defense Programs Office (DOE/DP), which has a representative on the Defense Technology Conversion Council, oversees the national weapons laboratories, nuclear material stockpiles, and the fabrication and testing of nuclear

weapons. In order to carry out these missions, DOE/DP has developed expertise in such fields as supercomputer applications, microelectronics, advanced materials, and lithography. For fiscal year 1993, DOE's weapons research, development, test, and evaluation budget is slightly less than $2 billion (see Table C-4). The Clinton Administration has proposed redirecting $47 million in 1993 R&D funds for nuclear weapons to expand research on dual-use technologies at DOE defense laboratories.

Under its Technology Transfer Initiative, DOE has helped finance numerous dual-use collaborative projects with cost-sharing arrangements. For example, DOE manages a $260 million research venture with the U.S. Advanced Battery Consortium to develop batteries for electric vehicles. DOE has also played a leading role in three interagency R&D initiatives through the Federal Coordinating Council on Science, Engineering, and Technology: mathematics and science education, high-performance computing and communication, and biotechnology. Because of its experience in administering collaborative programs and its expertise in certain advanced technologies, the Defense Programs Office will probably oversee some of the TRP partnerships and some manufacturing engineering education projects.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA's mission is to promote space exploration and aeronautics. Consequently, it conducts and sponsors a large amount of R&D with both civil and military applications, especially in two offices. The newly created Office of Advanced Concepts and Technology analyzes the feasibility of advanced technologies, promotes space commerce, and coordinates NASA's commercial, small business innovative research, and independent research and development programs. It sponsors research in fields such as automation, navigation and control avionics, optics, and communications systems and also funds projects at institutions of higher learning to improve engineering education. NASA's Office of Aeronautics also supports R&D in advanced aeronautics and high-performance computing and manages several NASA field centers. Because of its role in coordinating technology transfer, NASA's representative on the Defense Technology Conversion Council is the Associate Administrator of the Office of Advanced Concepts and Technology. NASA is likely to play a key role in TRP projects in civil aviation research (see Table C-5 for a breakdown of NASA's R&D funding).

TABLE C-4. DEPARTMENT OF ENERGY R&D BUDGETS BY MISSION
(By fiscal year, in millions of dollars)

R&D Programs	1991 Appropriation	1992 Appropriation	1993 Appropriation	1994 Request
Energy R&D	1,850.7	2,091.0	1,987.9	1,977.3
Science and Technology				
High-energy physics	628.0	618.4	613.4	627.8
Nuclear physics	354.4	351.4	309.1	322.3
Supercollider	242.9	482.6	517.0	640.0
Basic energy sciences	764.7	760.4	860.7	802.0
Other supporting research and technology applications	25.2	104.4	106.0	156.7
Advanced neutron source	0.0	0.0	0.0	39.0
Biological and environmental	393.9	369.5	385.2	416.1
Subtotal	2,409.1	2,686.7	2,791.4	3,003.9
Defense R&D				
Weapons research, development, test, and evaluation	1,737.1	1,943.9	1,955.4	1,784.5
Naval reactors	652.0	818.0	807.0	767.7
Subtotal	2,389.1	2,761.9	2,762.4	2,552.2
Environmental Restoration Technology Development	206.0	303.4	336.9	401.0
Total	6,854.9	7,843.0	7,878.6	7,934.4

SOURCE: Congressional Research Service.

TABLE C-5. NASA RESEARCH AND DEVELOPMENT BUDGET
(By fiscal year, in millions of dollars)

Projects	1991 Actual	1992 Actual	1993 Estimate	1994 Request
Space Station and New Technology Investments	1,900.0	2,028.9	2,122.5	2,300.0
Space Transportation Capability	602.5	719.5	649.2	649.2
Space Science and Applications	2,431.1	2,712.6	a	a
Space Science	n.a.	n.a.	1,519.6	1,631.9
Life and Microgravity Sciences and Applications	n.a.	n.a.	407.5	351.0
Mission to Planet Earth	n.a.	n.a.	937.9	1,074.9
Commercial Programs	88.0	147.6	165.4	172.0
Aeronautical Research and Technology	512.0	784.3	865.6	1,020.7
Space Research and Technology	286.9	314.8	272.7	298.2
Transatmospheric Research and Technology	95.0	4.4	0	80.0
Safety, Reliability, and Quality Asssurance	33.0	33.6	32.7	35.3
Academic Programs	55.1	66.8	92.9	74.5
Tracking and Data Advanced Systems	20.0	22.0	23.3	24.6
Advanced Solid Rocket Motor	309.1	315.0	195.0	280.4
Total	6,332.7	7,147.4	7,284.3	7,992.7

SOURCE: Congressional Research Service.

NOTE: n.a. = not applicable.

a. The office of Space Science and Applications was split into three offices in fiscal year 1993: the Office of Space Science, the Life and Microgravity Sciences and Applications Office, and the Mission to Planet Earth Office.

In the fiscal year 1994-1997 period, the Administration has proposed expanding NASA's civil aeronautics research by a total of $550 million and its short-haul aircraft research by $50 million. These proposals would be financed, in part, by redirecting some of the space station budget.

NATIONAL SCIENCE FOUNDATION

Among the federal agencies that sponsor R&D, the National Science Foundation has one of the broadest missions; it supports science and engineering among all disciplines. NSF awards grants to private research institutions, not-for-profit organizations, and colleges and universities to expand knowledge and promote stronger curricula. The agency also has experience supporting collaborative partnerships between universities and industry in many fields of advanced technology such as optoelectronics, composite materials, and data storage systems. Like NIST and the National Institutes of Health, NSF uses an extensive evaluation and ranking procedure in making its awards. Within the Defense Technology Conversion Council, NSF will play a primary role in administering the Manufacturing Engineering Education programs because of its extensive investments in improving engineering curricula (see Table C-6 for NSF's current funding). The Clinton Administration has proposed adding $2.3 billion to the agency's budget over fiscal years 1994-1997.

TABLE C-6. NATIONAL SCIENCE FOUNDATION FUNDING
(By fiscal year, in millions of dollars)

Projects	1991 Actual	1992 Actual	1993 Estimate	1994 Request
Research and Related Activity	1,703.6	1,871.1	1,862.0	2,204.8
U.S. Polar Research Program and Antarctic Logistics	175.1	87.4	222.4	228.2
Education and Human Resources (EHR)	322.0	441.4	487.5	556.1
Academic Research Facilities and Instrumentation	39.0	33.0	50.0	55.0
Critical Technologies Institute	0	0	1.0	1.0
EHR Graduate Trainees	0	23.0[a]	0	0
Carryover	69.6[b]	23.0[a]	28.5	0
Inspector General	2.9	3.9	3.7	4.1
Salaries and Expenses	100.9	110.0	111.0	125.8
NSF Headquarters Relocation	0	0	0	5.2
Total	2,413.1	2,547.1[a]	2,762.0[a]	3,180.2

SOURCE: Congressional Research Service.

a. Fiscal year 1992 appropriation for graduate traineeships will be carried over and obligated in fiscal year 1993. Carryover is excluded from the fiscal year 1992 total and included in the fiscal year 1993 total.

b. Fiscal year 1991 value for Mathematical and Physical Sciences excludes $69.6 million in obligations for the replacement of the Green Bank Telescope, which is shown as obligation of carryover.